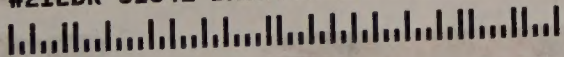




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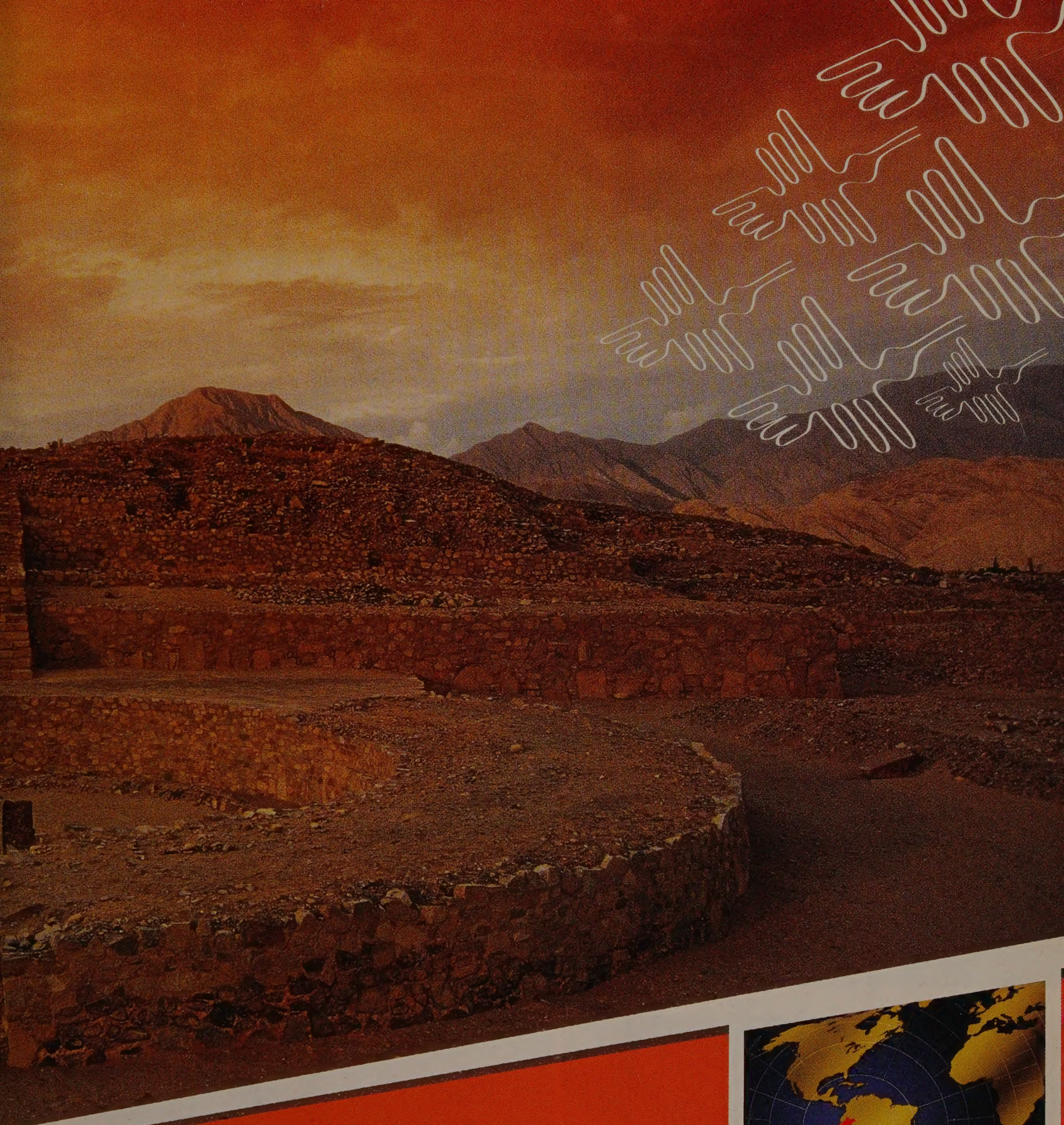


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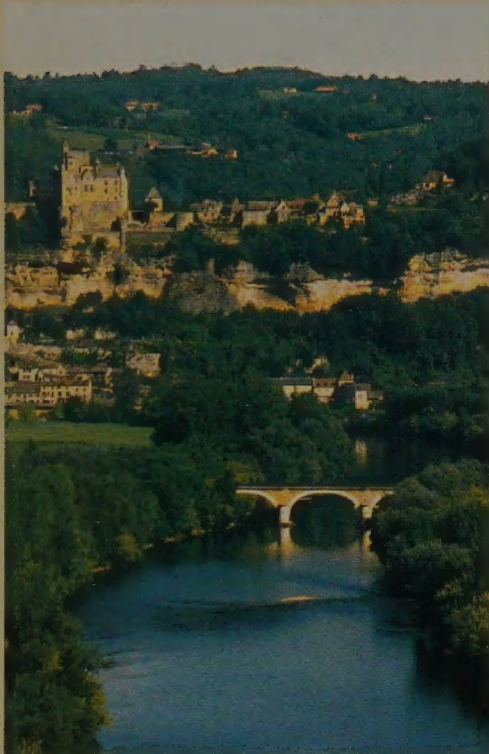
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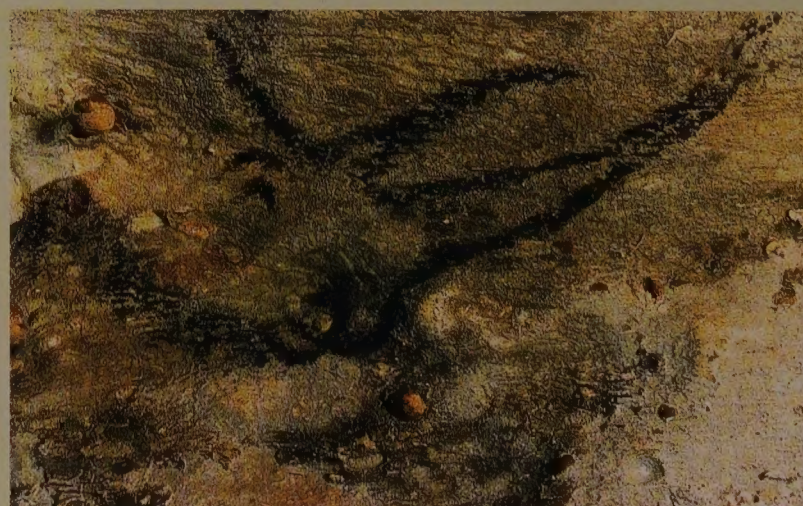
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NATURAL HISTORY

FEBRUARY 2007

VOLUME 116

NUMBER 1

FEATURES



COVER STORY

22 FACES OF THE HUMAN PAST

Science and art combine to create a new portrait gallery of our hominid heritage.

RICHARD MILNER AND IAN TATTERSALL



30 EIGHT ARMS, WITH ATTITUDE

Octopuses count personality, playfulness, and practical intelligence among their leading character traits.

JENNIFER A. MATHER



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Unexpected social behavior in an improbable arachnid, the whip spider

LINDA S. RAYOR

ON THE COVER: The hominid species *Homo rudolfensis* lived in East Africa between 1.8 and 1.9 million years ago. Illustration by Viktor Deak

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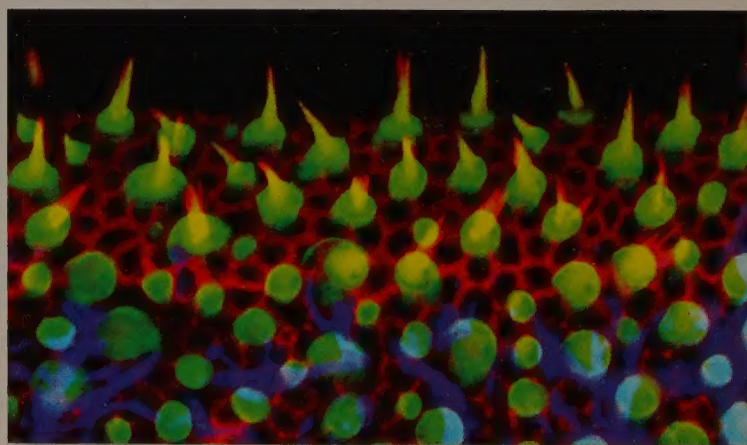
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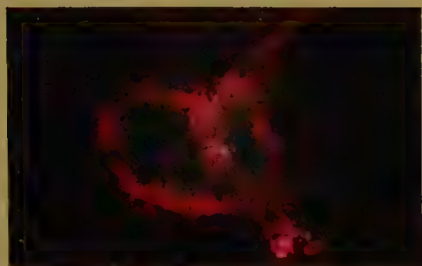
THE NATURAL MOMENT

Heart of the Matter

Photograph by Matthew T. Russell



◀ See preceding two pages



Revealing your heart to someone takes time. In the case of IC 1805—a hot cloud of gas near the constellation Cassiopeia—the revelation has taken 7,500 years. That's how long light from the cloud must travel through space to reach Earth. But close observers of the sky will find the long-distance relationship rewarding: through even a small telescope, the light from IC 1805 makes the pattern that inspired the cloud's common name, the Heart Nebula.

The Heart Nebula owes its color, size, and heart shape chiefly to a group of young, energetic stars clustered together in the nebula's center. The hot young stars emit ultraviolet radiation that, in turn, excites the gas around them. Most of the excited gas particles are hydrogen ions, so when those ions "relax" and recombine with free electrons, they throw off their extra energy as deep red light.

Photographer Matthew T. Russell caught the nebula on a charge-coupled device rigged to a four-inch refracting telescope this past September, from his personal observatory in Black Forest, Colorado. He tracked the patch of sky to make a five-and-a-half-hour exposure of the nebula, using four color filters to separate and re-create the nebula's colors.

As telescopes of Hubble-like proportion compete in a kind of technological arms race in space programs around the globe, Russell's photograph proves that the backyard telescope still has amazing potential, too. After all, who said you have to be big to capture a heart? —Erin Espelie

Hominid Time Machine

The year is 3.2 million B.C., the light is flattering, and for once, Og's face isn't covered with blood, grime, and the infected bites of tsetse flies. Doesn't someone have a digital camera? Regretfully, no. And no one, to my knowledge, has unearthed a pinhole image from that luminous day, inadvertently recorded for posterity on some nearby photosensitive rock.

So we're stuck. If today's descendants of Og and his tribe—us—want pictures of our distant ancestors for the mantel, we have to make 'em ourselves. Fortunately, the project is intriguing enough to attract institutional support and inspire such long-term organizational discipline that the most talented scientists and artists in the world find their way into the field. Meet Gary J. Sawyer (near right), Viktor Deak (far right), and their friends.

Sawyer is a physical anthropologist at the American Museum of Natural History in New York City; Deak is a paleoartist with that rare kind of virtuosity that can blow you away. Richard Milner and Ian Tattersall tell the story of their collaboration, and the history of their predecessors, in the text that accompanies the extraordinary images you'll find in "Faces of the Human Past" (page 22).

Yet isn't it presumptuous to suppose that an artist can envision such a distant past? Deak is explicit about his assumptions. With fossils from just one side of a face, his renderings are bilaterally symmetric. The underlying facial muscles lie at carefully calculated points along the anatomical path between contemporary primates and humans. Many of Deak's subjects look healthy, well fed, uninjured—artistic license, one might think—but he points out that modern gorillas are quite careful about their appearance. Even hair has an empirical basis: its thickness and coarseness reflect assessments of diet, activity level, and the role of sexual selection. The computer has become a powerful tool: in Photoshop, Deak can borrow what he wants from scores of images of contemporary primates, cutting and pasting so profligately that a single final image may be made up of 250 digital "layers" and consume a gigabyte on his hard drive.



Even though my editorial colleagues and I are "ink-stained wretches," devoted to *Natural History* as a print magazine, we understand that many readers today are informed and entertained through many other media. So won't you please write and tell me what you'd most like to see us add to our Web site? Take a look at the current site (www.naturalhistorymag.com) and then send your thoughts and suggestions to me by e-mail at nhmag@naturalhistorymag.com, or by mail at: *Natural History* Web Site, 36 West 25th Street, fifth floor, New York, NY 10010. —PETER BROWN

LETTERS

Darwin's Progress

I was somewhat startled by Laurence A. Marschall's statement, in his review of *Darwinism and Its Discontents* [10/06], that "nothing about the process of natural selection guarantees that things must get better with time." That may be true in some narrow, technical sense, but I am puzzled how anyone can examine the history of life on Earth and not notice

tendency to culminate in complex creatures like us.

There is, to be sure, a superficial appearance of progress, as Mr. Brown notes. Statistically, that is not surprising: complex creatures are more likely to appear late in the evolutionary sequence rather than early. But does that imply that we should single out those complex creatures as some end product? Far more new species of



"You're the dinosaur, not me."

the persistent drive toward complexity, culminating in human consciousness.

Dwight Brown
Kerrville, Texas

LAURENCE A. MARSCHALL REPLIES: Dwight Brown concedes that the undirected character of natural selection may be true in a technical sense, but he misses the point that the technical details of evolution are precisely what natural selection is about. The forces that determine the proliferation of one genotype over another are those of random mutation and population statistics, not a natural or supernatural

bacteria and viruses have evolved in the past week, it is safe to say, than all the hominid species that have ever evolved. Does that imply evolution aims to produce bacteria? Hardly.

Elephant's Thermostat

I must quibble with the illustration on pages 54 and 55 of John Tyler Bonner's article, "Matters of Size" [11/06]. The gazelle-size elephant wouldn't be able to maintain body temperature without some fur. Likewise, it would lose too much heat through radiation from those big floppy ears. Conversely, the giant elephant would overheat

without a better means of dissipating heat. As the text of the article makes clear, there are many effects of scaling beyond just the mechanical strength to support the body.

Jonathan Turetsky, D.V.M.
East Hampton, New York

JOHN TYLER BONNER REPLIES: Jonathan Turetsky is not quite on the mark, because the metabolic rate of the small hypothetical elephant would be much greater than that of the larger ones, which would help compensate for the problems he raises. But the point of that figure was simply to show that in a larger quadruped the legs must be thicker to support the increase in weight.

Light on the Dark

In "Times of Our Lives" [11/06], Robert L. Jaffe states that "like a sales tax, the dark energy is a fixed percentage of the newly created volume of space," implying (at least to a novice like me) that some sort of continuous creation is going on. Otherwise, it would seem that the "new" dark energy must have existed somewhere else in the universe, and just have been transferred to the new location. Please set me straight.

Fletcher Downey
Grass Valley, California

In his breathtaking article Robert Jaffe talks about a shift between matter and dark energy. Why should there be such a shift, and where is it originating from? Lika L. Levi
Scarsdale, New York

ROBERT L. JAFFE REPLIES: No one can stand outside our universe and watch it expand in three dimensions, but perhaps Fletcher Downey will find its two-dimensional analog helpful. Our universe is like the (two-dimensional) surface of a balloon as it is blown up. The galaxies, like spots inked on the surface of the balloon, are flying apart from one another and, as the balloon expands, new space is created. Furthermore, just as energy is stored in the taut surface of the expanding balloon, dark energy is also built up in the new space created by the expanding universe.

The "shift" that Lika L. Levi mentions comes about because the amount of matter in the universe is fixed, but the amount of dark energy grows as the universe expands. In fact, dark energy helps drive the expansion to go faster, so more dark energy causes more expansion, and in turn even more dark energy. The positive feedback makes the expansion of the universe rapid indeed once dark energy dominates: eventually it will cause the universe to "inflate" in much the same way that it did in the early "inflationary" era.

Taking Turns

Donald Goldsmith ["Turn, Turn, Turn," 12/06–1/07] describes three periodic motions of Earth: a daily rotation, a yearly revolution, and the 25,785-year precession of the rotation axis. There are two additional periodic motions—the
(Continued on page 12)

CONTRIBUTORS

An astrophotographer who works out of his own personal observatory in Black Forest, Colorado, **MATTHEW T. RUSSELL** ("The Natural Moment," page 6) gathers light from distant objects in the universe for several hours (if not multiple nights) to expose a single photograph. His images have been featured widely in publications such as *Astronomy* magazine and a recently released book by the late Carl Sagan, *The Varieties of Scientific Experience: A Personal View of the Search for God* (Penguin Press, 2006). Check out www.telescopes.cc for more of Russell's photographs of the night sky.



Milner



Tattersall

RICHARD MILNER and **IAN TATTERSALL** ("Faces of the Human Past," page 22) have been closely following the reconstructions of early hominids by Gary J. Sawyer and Viktor Deak, some of which will appear in a new hall of human origins that opens this month at the American Museum of Natural History in New York City. The reconstructions also appear in the book *The Last Human: A Guide to Twenty-two Species of Extinct Humans*, which is being published this month by Yale University Press, and from which the photographs that accompany this article have been selected. Milner is an associate in anthropology at the American Museum, and a contributing editor at this magazine. His book *Darwin's Universe* will be published this year by the University of California Press. Tattersall, a curator in the division of anthropology at the American Museum, oversaw the installation of the museum's Hall of Human Biology and Evolution in 1993 and has been co-curator of its newly updated successor. A frequent contributor to *Natural History*, Tattersall is the author of several books, most recently, with Rob DeSalle, *Human Origins: What Bones and Genomes Tell Us about Ourselves*, which will be published this month by Texas A&M University Press.

Growing up in Victoria, British Columbia, in a family fond of sailing, **JENNIFER A. MATHER** ("Eight Arms, With Attitude," page 30) was often on or near the ocean. Originally fascinated by shore animals, she eventually came to study one of the full-time inhabitants of the sea, the octopus. A primary focus of her research is comparative cognition, the patterns and "specialties of thinking" in many different animals. Collaborating with Roland C. Anderson of the Seattle Aquarium, she conducted the laboratory studies she describes in these pages. Mather is a professor of psychology at the University of Lethbridge in Alberta.



As an undergraduate, **LINDA S. RAYOR** ("Family Ties," page 38) landed her first paying job observing how mother macaques interact with their offspring. Little did she realize at the time that her own research would explore similar interactions—mother-young behavior that helps structure social organizations—but in quite different creatures: the amblypygids, or whip spiders, that she describes in her article (and displays above), as well as ground squirrels, huntsman spiders, and prairie dogs. Rayor is at work on a book with a colleague, Cole Gilbert, and a photographer, Joseph Warfel, on spider behavior. She is a senior research associate in the entomology department at Cornell University in Ithaca, New York.

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The International AIDS Vaccine Initiative (IAVI) is a global nonprofit organization searching for safe, effective, and accessible AIDS vaccines.

The organization recently formed an international public/private partnership with the Imperial College of Science, Technology and Medicine in London to foster AIDS vaccine development.

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LETTERS

(Continued from page 9)

Milankovitch cycles—one associated with a change in the Earth's tilt, with a period of 40,000 years, and another associated with a change in the eccentricity of Earth's orbit around the Sun, with a period of 100,000 years. The latter motion has had the biggest impact on Earth's climate, resulting in a 100,000-year cycle of ice ages and warming periods.

Matthew Brzostowski
Houston, Texas

Could Donald Goldsmith explain why precession doesn't affect when in the year the seasons occur? From the diagram on page 22 it would appear that the time of year that winter and summer occur should

switch every 13,000 years.
Elliot Ofsowitz
Sarasota, Florida

DONALD GOLDSMITH REPLIES: Matthew Brzostowski is correct that in addition to the slow wobble of its rotation axis, the Earth has an even slower cycle of change in the amount by which its rotation axis tilts from being perpendicular to its orbital plane, and another slow cyclical change in the elongation ("eccentricity") of its orbit. Those cycles, often collectively referred to as the Milankovitch cycles, are worthy of examination in a future article.

The answer to Elliot Ofsowitz's question depends on the difference between the tropical and sidereal years. The tropi-

cal year is the time interval from one vernal equinox to the next. Precession affects that interval, but, by definition, the seasons must always occur at the same times of the tropical year, because the vernal equinox always marks the beginning of spring in the Northern Hemisphere. The sidereal year is the time for Earth to complete an orbit with respect to the so-called fixed stars. Hence it determines which stars (and constellations) appear in the sky in various months. Precession leads to a repetitive cycle in the night sky, with respect to the seasons of the tropical year.

DMZ Paradox

I found Mary Mycio's essay "Chernobyl Paradox" [4/06] fascinating reading,

all the more so because I had just returned from a trip to South Korea and the Demilitarized Zone (DMZ) that separates South and North Korea. With nothing except watchtowers along the 2.5-mile-wide strip that divides the entire peninsula, fauna and flora thrive there. If the two countries become peacefully united, one hopes the area could be left as a nature preserve.

Howard S. Edelstein
New York, New York

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Cloudmakers

Phytoplankton—single-cell marine organisms—may be microscopic, but they can also play a sizable role in regulating the Earth's climate. A recent study of their chemical emissions could change climate forecasts, though whether for better or worse remains unknown.

The chemical emissions form airborne particles around which water droplets grow, giving

rise to clouds. Warmth causes phytoplankton to multiply, but the clouds they make filter the Sun's rays, cooling the Earth's surface. The system has been known for two decades.

Two atmospheric scientists, Nicholas Meskhidze, now at North Carolina State University in Raleigh, and Athanasios Nenes of the Georgia Institute of Technology in Atlanta, studied satellite images of an immense, periodic bloom of phytoplankton in a remote area of the Southern Ocean. Sure enough, when the bloom waxed, the clouds overhead became bigger, denser, and more opaque to solar energy than when the bloom waned.

But Meskhidze and Nenes discovered a gap in that tidy logic when they ran a computer

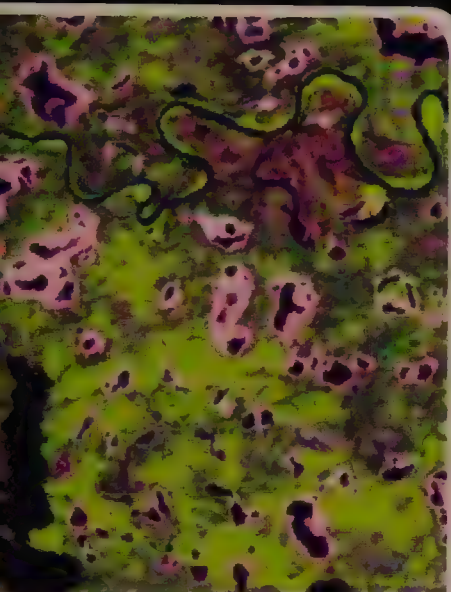
simulation of the Southern Ocean system. The dimethyl sulfide from phytoplankton, long thought to be the chemical responsible for the clouds, couldn't consistently yield enough water droplets to account for the extra clouds observed during large blooms. So the team plugged isoprene, another chemical made by phytoplankton, into the model—and out popped the extra clouds.

If confirmed at sea, that chemical shake-up will force climate models to replace some dimethyl sulfide with isoprene, a chemical whose properties may change climate forecasts in unforeseen ways. What's more, how phytoplankton will respond to global warming remains unknown. If they flourish, more clouds may put some brakes on

Chaetoceros sp., a marine phytoplankton, magnified 1,600x

the warming. If their populations crash, fewer clouds may accelerate the warming instead. And phytoplankton also affect climate by absorbing carbon dioxide, a major greenhouse gas. Never underestimate the power of the very small! (*Science*)

—Rebecca Kessler



False-color satellite image of Alaskan lakes was made in 2001. The 1952 lakeshores (pink overlay) show what has been lost.

Out to Dry

Lakes in Alaska are vanishing, and the most probable culprit is—you guessed it—global warming. A trio of ecologists led by Brian Riordan at the University of Alaska Fairbanks analyzed aerial images from the past half-century to track changes in the

surface areas of the lakes in nine regions throughout the state.

The investigators spatially aligned digitized aerial photographs from the 1950s, infrared aerial photographs taken between 1978 and 1982, and digital satellite images taken between 1999 and 2002, then manually

outlined each lake in the images. The result is a meticulous inventory of more than 10,000 lakes. The investigators then estimated the change in the number of lakes and the area of their surface waters. They also compiled meteorological data for each of the nine regions.

Since the 1950s, they discovered, the total surface area of the lake water in eight of the nine study regions shrank by 4 to 31 percent. What's more, the total number of lakes in all nine regions declined by 5 to 54 percent. And mean annual temperatures increased significantly.

The shrinkage could be caused by any of several effects of rising temperatures, the ecologists argue: increased water loss through evaporation, increased transpiration by nearby vegetation during the longer, warmer growing seasons, or increased drainage into the surrounding soil as the permafrost thaws. In any case, the phenomenon may be a first sign of more widespread changes to come. (*Journal of Geophysical Research*)

—Graciela Flores

Bug Life

How will insects, the most abundant animals on Earth, respond to a warmer climate? The answer lies in a basic tenet of biology: at higher temperatures, biochemical reactions happen faster. The principle is particularly relevant for insects and other ectothermic organisms, whose body temperatures depend on the environment.

Consequently, some biologists argue that "warmer is better": species adapted to warmth should always out-reproduce their cold-adapted cousins. Those biologists reason that biological processes—locomotion, metabolism, reproduction, and the like—in organisms from cold regions

inevitably run more slowly than in their counterparts from warmer climes. But other investigators counter that natural selection can enable cold-adapted organisms to achieve rates of reproduction and other processes that match those of warm-adapted species.

To probe the issue in insects, Melanie R. Frazier, her graduate adviser, Raymond B. Huey, an evolutionary physiologist at the University of Washington in Seattle, and a colleague compiled data on rates of population growth in sixty-five insect species. The team discovered that at their optimal temperatures, species from warm regions tend to be more prolific than species from cold regions. The results support the

"warmer is better" hypothesis.

The results also highlight a largely unforeseen consequence of global warming: an overabundance of insects. Frazier estimates, for instance, that a warming of just two Fahrenheit degrees would nearly double the number of offspring from a single whitefly (*Bemisia argentifolia*), a crop pest that already produces 1.3 million offspring in a three-month period.

Of course, not all insect species will adapt to warmer temperatures. Some will disappear and others will move to cooler regions. But perhaps, as in B movies, the ones that remain will indeed take over the world. (*The American Naturalist*)

—G.F.

But Did They Do It?

When early modern humans spread through Europe some 35,000 years ago, they almost surely met Neanderthals. But did members of the two groups mate and procreate before the Neanderthals died out? The question has spurred debate since soon after the first Neanderthal fossil was unearthed in 1856. A number of anthropologists think the two groups were similar enough biologically, and perhaps even behaviorally, cognitively, and socially, that sexual encounters—and the offspring thereof—were inevitable. Others, however, contend that the two groups' genes never mingled. A flurry of new discoveries in the fossil and genetic records strengthens both sides of the argument, leaving the central question unanswered.

New evidence that interbreeding took place comes from Bruce T. Lahn, a geneticist at the University of Chicago, and several colleagues. Writing in the journal *PNAS*, they report tracing the history of an allele, or version, of a gene that regulates brain size, and discovering that it originated in archaic hominids some 1.1 million years ago. That was around the time the lineage leading to modern humans branched off, sans allele.

The allele later appeared in the modern human genome around 37,000 years ago. Lahn proposes that the allele was introduced to the modern human genome through interbreeding—perhaps even a single one-night stand—between a Neanderthal or other archaic hominid and an early modern human.

Erik Trinkaus, an anthropologist at Washington University in St. Louis, Missouri, and two colleagues recently examined 31,000-year-old modern-human bone fragments from Romania. As with other remains he has studied from the same period, Trinkaus writes in *PNAS* that the bones exhibit a mixture of modern human and Neanderthal traits. The latter include a distinctive bulge in the back of the skull, characteristic muscle-attachment points on the lower jaw, and shoulder blades that lack adaptations for throwing. Because not all of his samples share the same Neanderthal-like traits, Trinkaus argues that early modern humans, which formed the larger population, gradually absorbed the Neanderthals, begetting hybrids along the way.

Two recent studies of the Neanderthal genome, by contrast, suggest that the two groups are unlikely to have interbred. Both are based on genetic material initially isolated from a 38,000-year-old Neanderthal

femur by Svante Pääbo, a paleogeneticist at the Max Planck Institute in Leipzig, Germany, and his colleagues. Pääbo's team, writing in *Nature*, and another group led by Edward M. Rubin, a geneticist at the Joint Genome Institute in Walnut Creek, California, writing in *Science*, independently compared portions of the Neanderthal genome to our own and to that of chimpanzees. Both teams concluded that even though the modern human and Neanderthal genomes are more than 99.5 percent identical, the two groups diverged around 400,000 years ago, and interbred little, if ever, during the intervening years.

Although no signs of interbreeding or the allele studied by Lahn have yet surfaced in the Neanderthal genome studies, investigators can't rule out the theory that early modern humans and Neanderthals produced offspring until the Neanderthal genetic blueprint is completed, probably in late 2008. Even then, however, the genome of a single Neanderthal won't tell the whole story about interactions between the two groups.

"The debate," says Osbjorn M. Pearson, an anthropologist at the University of New Mexico in Albuquerque, "is as alive as ever."

—Corey Binns

The Beast of Kings

Two medieval lions have lurked unnoticed in the Natural History Museum in London for decades. Their skulls, along with those of a leopard and nineteen dogs, were discovered during a 1937 archaeological excavation of the Tower of London. But their significance has only now been made clear. Radiocarbon dating by Hannah O'Regan, an archaeologist at Liverpool John Moores University in England, and two colleagues shows that the two lions are the only big cats ever unearthed that date to medieval Britain.

The lions, which lived between the thirteenth and fifteenth centuries, and the more-



Skull of a lion kept in London's Royal Menagerie in medieval times

recent leopard (alive sometime between 1440 and 1625) were part of the Royal Menagerie established in London by King John, who reigned from 1199 to 1216. A section of the Tower of London called the Lion Tower housed an array of exotic crea-

tures that, despite their rarity and connotation of royal power, were sometimes the star attractions in blood sports, such as baiting by dogs. Records from the mid-sixteenth century indicate that the Tower's animals weren't exactly housed in luxurious conditions, either: they lived in cages so cramped they had little room to turn around. In 1831 the last surviving inmates were moved to the newly established London Zoo, and the Lion Tower was demolished

two decades later. After they died, the bodies of the lions, leopard, and dogs appear to have been unceremoniously dumped in the Tower of London's moat. (*International Journal of Osteoarchaeology*)

—Nick W. Atkinson

Silent Alarm

It pays for lovelorn male *túngara* frogs to listen while they call for mates in the dangerous jungle twilight. A sudden silence that interrupts the chirping, chucking, trilling, and whining of a frog chorus might herald the arrival of an unwelcome



Squid Secrets

As any squid knows, visual communication is a wonderful way to convey a message. It has a major downside, though; predators can tune in to the broadcast just as readily as the intended recipients (other squid) can. A recent study by Lydia M. Mäthger and Roger T. Hanlon, both biologists at the Marine Biological Laboratory in Woods Hole, Massachusetts, suggests that squid—and most likely their close relatives, cuttlefish and octopuses—have evolved a secret communication channel to which

their predators are oblivious.

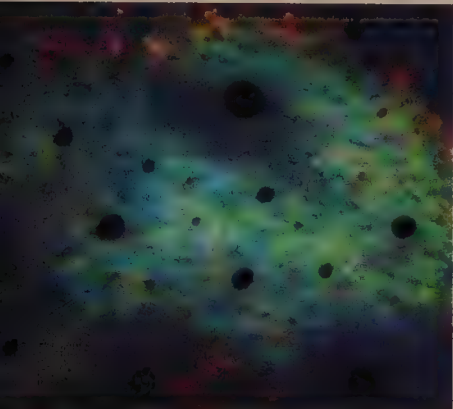
Squid, cuttlefish, and octopuses are known for their ability to change their skin color in a spectacular way. They can blend instantly into the background or produce a startling array of patterns and hues to express their physiological or motivational state [see “Eight Arms, With Attitude,” by Jennifer Mather, page 30]. The secret to the show is the two distinct layers of cephalopod skin: The inner layer of iridophore cells is both iridescent and reflects polarized light. The outer layer is made up of pigmented organs, or chromatophores, which expand or contract to help change the color or pattern of the skin.

Cuttlefish, octopuses, and squid have a visual system to match the complexity of their

skin.

Unlike their vertebrate predators, they can detect differences in polarized light. Mäthger and Hanlon discovered that the two skin layers work independently, and that by taking advantage of the reflective properties of the iridophores, squid may be able to communicate with other squid via polarized light. At the same time, the squid can camouflage themselves from predators by altering the color pattern in the chromatophore layer, through which polarized light travels freely. What happens among squid stays among squid! (*Biology Letters*) —N.W.A.

Squid skin (left, magnified 9×) has an inner layer that is iridescent and transmits polarized light through dark, overlying camouflage spots. Common squid is pictured at top.



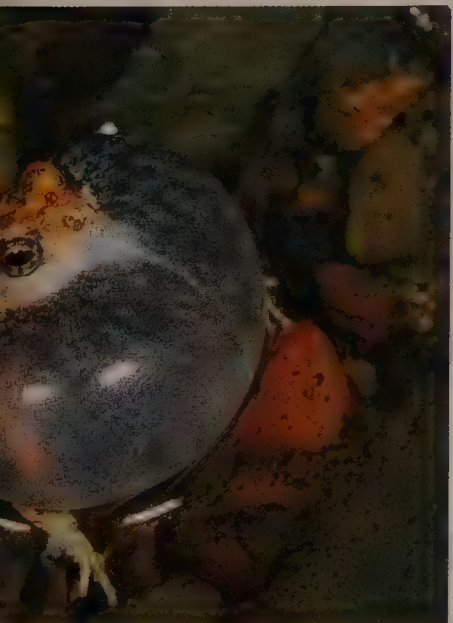
bat, snake, or other predator. A study by Steven M. Phelps, a zoologist at the University of Florida in Gainesville, and two colleagues now suggests that male túngaras (*Physalaemus pustulosus*) don't listen just for their own species' refrain, they eaves-

drop on other species, too.

To determine how much attention túngara frogs pay to the calls of their own and other species, Phelps's team fooled captive male túngaras into thinking they were under attack. The team played a túngara chorus, then interrupted it while mimicking the appearance of an aerial predator (they slid a plastic plate along an overhead wire). After a brief pause, they presented the túngaras with one of four stimuli: the recorded call of a single frog of one of three species or silence (as a control). Then they measured how quickly and vigorously the túngaras resumed calling.

The investigators discovered that male túngaras pay nearly as much attention to the

Male túngara frog sings for a sweetheart.



calls of *Leptodactylus labialis* frogs as they do to those of their own species. What was important about *L. labialis* was its geographically overlapping range, not the sound of its calls: the túngaras all but ignored a closely related species, *P. eneseae*, whose calls are similar to their own, but whose range does not overlap. Phelps surmises that túngaras attend to species with overlapping ranges because they share the same dangers of predation.

By eavesdropping on the calls of other frog species, túngaras can maximize both survival and reproduction: they enhance their predator early-warning system while reducing their time spent in silence. After all, the jungle rewards with mates or punishes with death in an instant. (*Behavioral Ecology*) —N.W.A.

Vitriphagy

Microorganisms can live in the most extreme environments, feed on a host of seemingly inedible materials, and thrive on improbable sources of energy. Can they possibly still surprise us? Try this: they feed on glass inside submarine volcanoes.

Recently Hubert Staudigel, a marine volcanologist at the Scripps Institution of Oceanography in La Jolla, California, and four colleagues published a comprehensive paper augmenting the evidence that distinctive pitting in underwater volcanic glass from around the world is of biological origin.

The evidence includes telltale microscopic textures in the glass, such as spiral tunnels and branching tunnels, which are hallmarks of microbial activity. The paper also points to the presence of carbon isotopes characteristic of life, as well as microbial DNA, in the tunnels. The microorganisms apparently dissolve the glass with acid.

The evidence for glass alteration by microorganisms occurs throughout the uppermost thousand feet of oceanic crust, suggesting that the process may be playing an important role in cycling elements between seawater and the seafloor. And because volcanic glass dates to 3.5 billion years ago, the authors argue, it might be just the place to look back in time for the most ancient forms of life. (*GSA Today*) —G.F.



Volcanic glass altered by microorganisms, magnified 2,500×

Little Neutral Ones

In John Updike's memorable description, "The earth is just a silly ball/To them, through which they simply pass."

By Neil deGrasse Tyson

You'd never know it, but 6 trillion subatomic particles pass through every square inch of your body every second at nearly the speed of light. Most are leftovers from the big bang, but others arrive fresh from their superhigh-energy origins near black holes, deep inside gamma-ray bursts and supernovas, and within the core of our Sun. They zip across space, pass through your flesh and bones as though you didn't exist, and continue heedlessly on their way.

Before these particles were actually discovered, the Austrian physicist Wolfgang Pauli hypothesized their existence. In a letter to his colleagues, written in December 1930 and addressed to "Dear Radioactive Ladies and Gentlemen" (yes, that's physics humor), Pauli proposed an electrically neutral particle that he called a neutron. It was, he admitted, "a desperate remedy to save . . . the law of conservation of energy"—a law that, to the surprise of his colleagues, appeared to be failing on the subatomic level.

Two years later the English physicist James Chadwick discovered a relatively massive neutral particle residing contentedly in the atomic nucleus. Soon the name "neutron" was bestowed on it. But that nuclear neutron was not Pauli's; his hypothetical savior had to be much less massive. A year later the Italian physicist Enrico Fermi named Pauli's still-undiscovered particle the neutrino, Italian for "little neutral one."

Photomultiplier tubes catch the flash of blue light generated by a neutrino interacting with an atom in a detector deep underground.

Along with the photon, the electron, and the less-familiar quark, the neutrino lays claim to being one of the fundamental, indivisible building blocks of nature. Pauli had tactfully remarked in his 1930 letter that if such a particle existed, physicists should already have seen one. Not long afterward he confessed, in a candid assessment of what he had wrought, "I have done a terrible thing. I have postulated a particle that cannot be detected."

But it could be. Indeed, it was. Just after the Second World War two American physicists, Clyde L. Cowan Jr. and Frederick Reines, realized that the place to search would be a nuclear reactor, where, as in a nuclear bomb, disruptive changes to atomic nuclei lead to the prodigious emission of neutrinos. So they looked in the Savannah River Plant, a just-finished underground fission reactor near Aiken, South Carolina, built to produce tritium and plutonium for the Cold War nuclear arsenal of the United States. The physicists' first task was to find a way to capture these most antisocial of particles. Their second task was to disentangle the properties, behavior, and effects of the neutrino from those of all other subatomic particles liberated by their experiment. In 1956, based on their detection of a unique particle "signature," they announced the discovery of the neutrino.

Pauli proposed his new particle because of his confidence in the laws of conservation, which are among the most highly tested and fertile ideas in science. "Conservation," to a physi-

cist, does not refer to recycling or to safeguarding endangered habitats. It's the shorthand way to say that certain properties of nature remain unchanged during a controlled experiment, no matter what you do to it, no matter what anybody else does to it, and no matter what nature does to itself. Conserved properties include momentum, the total quantity of mass and energy, and the net electric charge. Run the experiment, and when you're done, the stuff you take out of the box must be the same as the stuff you put into the box—for all properties described by the laws of conservation.

Take momentum, which is motion coupled with direction. Imagine twin ice skaters standing still and facing each other, palms touching. This two-skater system has zero momentum, and since it's resting on slippery ice, it has only negligible attachment to Earth. If the twin skaters—two objects with the same mass—push away from each other, they will glide apart in opposite directions at the same speed. The momentum of one skater cancels that of the other, leaving the system as it started, with a net momentum of zero.

Arithmetically, momentum is just mass times velocity, so various kinds of pairs can still cancel. For example, if one skater has twice the mass of the other, the chubbier one will glide away at half the speed of the thinner one, again leaving the system's total momentum at zero. Rockets do much the same thing. Spent fuel spews out the back while the body recoils forward, leaving the momentum of the entire system unchanged from its prelaunch repose on the launch pad.

Even when rocket engines are anchored to the ground while fired (which is what goes on at testing facilities), something's got to give. Typically, the rockets are mounted horizontally and connected securely to Earth by cement piers. When the high-velocity exhaust blasts out the nozzles, it's planet Earth that recoils, ever so slightly, in the opposite direction. So a lazy but perverse engineer could point all the

world's test rockets due east—in the direction of Earth's spin—and ignite them, just to shorten the workday.

The conservation of total mass and energy has illustrious roots. Before Einstein proposed his most famous equation, mass-energy conservation was instead the conservation of mass and, separately, the conservation of energy. The universe was endowed with a certain amount of each, presumed from the experiments of the day to be changeless. But at the turn of the twentieth century, the discoveries of radioactivity and other bizarre phenomena within the atom indicated that mass could become energy, and energy could become mass. The conversion recipe was none other than $E = mc^2$.

Another conserved quantity is electric charge. Protons carry a unit of positive charge, electrons carry the same amount of negative charge, and neutrons carry no charge at all. Charge conservation requires that at no time during an experiment is the net charge anything other than what you started with. And that's as true for particle accelerators on Earth as for supernova explosions in distant galaxies.

Armed with the conservation laws of momentum, mass-energy, and electric charge, you're more or less where Pauli was in 1930. Back then, life was simpler. Particle physicists were not yet talking about quarks, muons, gluons, or Higgs bosons. What they did discuss was a subatomic process called beta decay, in which a proton and an electron spontaneously fly apart, accompanied by unbalanced momentum and a loss of mass-energy. Had the conservation laws lost their grip on nature? Or could the existence of an unforeseen and undiscovered particle resolve the conundrum?

Discoveries in physics often emerge from one's confidence in competing ideas. Rather than dismantle the foundations of physics, Pauli postulated that the escaping proton and electron (both later shown to have come from a decayed neutron) were not the sole products of the decay. His additional

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particle was to have no charge, some momentum, and vanishingly small, possibly zero, mass-energy.

Turns out, the key to beta decay was not the neutrino but its antimatter counterpart, the antineutrino. A decaying neutron yields a proton, an electron, and an antineutrino. Under the dictates of additional conservation laws, unknown to Pauli and his contemporaries, that's just what you'd expect. Two of those laws decree that no process can change the net numbers of heavy particles (baryons) and light particles (leptons). If your experiment starts with one baryon (a proton or a neutron), it must end with one baryon. That means a neutron can morph into a proton. And if it starts with zero leptons (an electron or a neutrino), it must end with zero leptons.

Wait a minute. Beta decay starts with zero leptons but ends with two leptons: an electron and an antineutrino.

Not to worry. The antineutrino is not simply a light particle; it's an anti-light particle. So in the particle count, an electron and an antineutrino cancel, resulting in zero net leptons. The laws of conservation triumph yet again.

Pauli died in 1958. Fortunately for him, he lived just long enough to see Cowan and Reines detect his "undetectable" particle. Today neutrinos remain among the most challenging subatomic particles to catch, even though everybody and everything is steeped in trillions of them. Problem is, they interact so rarely with other kinds of matter that you need enormous, clever traps to boost your chances of detecting any at all.

Nearly all the evidence for neutrinos from space comes from detectors buried deep underground, which hold enormous quantities of odd liquids surrounded by unusual hardware. These underground "telescopes" can catch intrepid neutrinos from any direction, even those that have passed all the way through Earth from below. In one detector the neutrinos enter a tank filled with 600 tons of chlorine-

laden dry-cleaning fluid. Every so often, in a kind of reverse beta decay, one of the passing neutrinos changes a resident neutron within a chlorine atom into a proton, thereby changing the chlorine to radioactive argon. The presence of an argon atom serves as a tracer of the neutrino's visit. Other creative designs track the flash of blue light emitted by the particle products of neutrino interactions. Those tanks are filled with ultrapure water or a mixture of baby oil and benzene.

My favorite setup, though, is a not-yet-finished neutrino observatory called IceCube. Its "tank" is a cubic kilometer of clear, dense Antarctic ice, in which the investigators will suspend a lattice of sensors, lowered through deep holes melted by a hot-water drill.

Unfortunately, Pauli didn't live long enough to see how populous the particle zoo would become—how many categories and subcategories and families and flavors particle physicists would postulate and discover in the decades that followed his death. Nor could he have imagined that neutrinos themselves would land in the middle of one of the greatest astrophysical conundrums of the twentieth century.

In March 1964, in the journal *Physical Review Letters*, the late American astrophysicist John N. Bahcall published his calculations showing that vast quantities of neutrinos should continually flee the Sun as the nuclear furnace in its core transforms hydrogen into helium. In a tandem paper, Bahcall's friend and colleague Raymond Davis Jr. described an experiment he was building in the disused Homestake Gold Mine in Lead, South Dakota. In search of evidence for solar neutrinos, he would place a tank of chlorine-rich liquid deep belowground. As usual, the encounters between neutrinos and atoms would be exceedingly rare; Bahcall calculated that the experiment should record about ten neutrinos a week. But even those few neutrinos would reveal what was going on in the

Sun's center, thus eliminating the need ever to visit the place.

For years, however, only about three of the ten neutrinos showed up. That gap became the tenacious "solar-neutrino problem." Some physicists copped an attitude, suggesting that astronomers didn't fully understand how the Sun manufactures energy—knowledge that underpins much of modern astrophysics. Shaken but not stirred, Bahcall was so sure the Sun was not misbehaving that he committed much of his career to demonstrating why. Meanwhile, Davis continued to refine his measurements. And the solar-neutrino problem endured.

Normally, physicists hand the laws of physics to astrophysicists, and it's those laws that guide questions and constrain answers. But every now and then, astro folks teach the physics folks a thing or two about how the universe works. Indeed, Bahcall was right all along. The missing neutrinos were there. They just weren't the kind of

neutrinos that would turn chlorine into argon. Apparently, without telling anybody, they had left the Sun with one identity—the one the experiment was designed to detect—but reached Earth in a different guise, requiring a different experiment to be detected at all.

Turns out, neutrinos come in three flavors, representing three regimes of energy in the universe. Not that you asked, but they're called the electron neutrino (low energy), the muon neutrino (middle energy), and the tau neutrino (high energy). So if your apparatus is designed to detect electron neutrinos, such as the ones forged in the core of the Sun, then the other neutrinos will pass undetected. Furthermore, if your experiment is designed to detect neutrinos of any regime, but antineutrinos are what come your way, you'll miss them, too. As with so much else in life, you need to know in advance what you're looking for.

But detection is only part of the challenge. Next comes the urge to compile a list of the neutrino's properties, beyond its neutral charge and its elusiveness. How about mass? All attempts to measure this basic property had failed so miserably that, until recently, physicists were uncertain whether the neutrino had any mass at all.

Here's where things get spooky.

According to Einstein's special theory of relativity, an onlooker who views a material object traveling at ever-greater speeds will see the object's mass increase, its time slow down, and its length shorten in the direction of motion. At the speed of light, its mass would become infinite, its time would stop, and its length would shorten to zero—all of which led Einstein to the sensible conclusion that physical objects can never attain light speed. Not only that, the reverse is true as well: if the thing has no mass whatsoever (if it's

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a photon, say), it must always travel at the speed of light.

So if the neutrino exists but has no mass, then it must travel at the speed of light. And if it travels at the speed of light, its own passage of time has stopped, leaving it with no internal "clock" to judge how old it is. To an outside observer, the neutrino's identity would forever be what it has ever been.

But if the neutrino has mass, it must travel more slowly than light, and must therefore bear an internal clock that actually ticks—one that recognizes the passage of time. And if the neutrino undergoes the passage of time, as other particles do, then it can transform itself. Unlike the neutron, however, which can decay into fundamental particles, the neutrino is already a fundamental particle. All it can do, then, is transform into another variety of neutrino. So if someone were to build an apparatus that could detect muon neutrinos or tau neu-

trinos, rather than only the garden-variety electron neutrinos detectable in Davis's setup, maybe all ten of Bahcall's neutrinos would show up.

And that's exactly what's happened.

John Bahcall had proceeded on the perfectly plausible assumption that the Sun's supply of electron neutrinos would simply remain electron neutrinos. But by the time they arrived on Earth, two-thirds of them had changed into muon and tau neutrinos, a process called neutrino oscillation. Imagine that somebody threw you a baseball, but it turned into a football in midflight. If you were looking only for the baseball, the football might pass unnoticed.

Once you know a neutrino can transform itself, you know it has a self-timer. You also know it cannot be traveling at the speed of light, which means it must have mass. As of March 2006, courtesy of a beam of muon neutrinos sent from Illinois to Minnesota, physicists can

say with confidence that the mass of the neutrino is no more than $1/2,000,000$ the mass of the already tiny electron, itself checking in at about $1/2,000$ the mass of the proton.

Knowing that the neutrino can switch identities and has very small (but nonzero) mass, astrophysicists have revisited earlier calculations that assumed a massless neutrino. Their efforts have lengthened the list of cosmic dramas in which the neutrino plays more than a bit part. Astrophysicists have not seen the last of the little neutral ones. For all we know, neutrinos hold the answers to questions already posed, as well as to questions not yet imagined.

Astrophysicist NEIL DEGRASSE TYSON is the director of the Hayden Planetarium at the American Museum of Natural History. He also hosts the PBS television series NOVA scienceNOW. Tyson's latest book is Death by Black Hole: And Other Cosmic Quandaries (W.W. Norton, 2007).



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Faces of the Human Past

*Science and art combine to create
a new portrait gallery of our hominid heritage.*

By Richard Milner and Ian Tattersall

Illustrations by Viktor Deak and Gary J. Sawyer

Judging from their astonishing paintings and engraved images of animals on the walls of European caves—works that have somehow survived since prehistoric times—people have been making pictures for at least thirty millennia, and probably for a lot longer. In contrast, attempts by scientists and artists of our own day to make credible likenesses of the cave painters and their more remote evolutionary antecedents go back a mere 150 years. In fact, scientific evidence for prehistoric humans was not generally recognized much before then.

One of the earliest published reports was that of the English antiquarian John Frere, who in 1800 presented his *Account of Flint Weapons Discovered at Hoxne in Suffolk*. Workmen digging clay for bricks had come across finely worked flint hand axes in a layer of gravelly soil, sealed beneath a sandy layer sprinkled with mammoth bones. Frere concluded that the tools were “fabricated and used by a people who had not the use of metals. [They lived in] a very remote period indeed; even beyond that of the present world.”

Although Frere’s discovery went unnoticed until long after his death, further evidence of early humans continued to accumulate. Following the lead of the French prehistorian

Jacques Boucher de Perthes, who trained workmen to search for stone hand axes in the 1840s, others began to seek and find quantities of prehistoric stone tools all over Europe. Part of a fossilized Neanderthal skull was discovered in a cave in the Neander Valley, near Düsseldorf, Germany, in



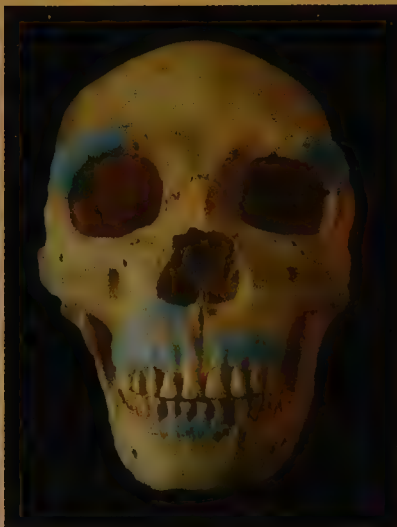
Portrait of a three-year-old female *Australopithecus afarensis* (left) is based on a fossil recently unearthed at Dikika, a site in the Afar region of northern Ethiopia. An early bipedal ape that stood three and a half to four and a half feet tall when fully grown, the species was first known from the famous “Lucy” skeleton discovered just six miles from Dikika in 1974. It had a chimpanzee-size brain but humanlike tooth patterns. Lucy lived 3.2 million years ago; the Dikika child dates from 3.3 million years ago. Above: An adult male *A. afarensis* glares at an intruder while taking a cooling dip in a lake. The aquatic setting is based on recent observations of gorillas in the wetlands of the Congo forest, where they like to wade and forage for aquatic plants.

Dissection in Reverse

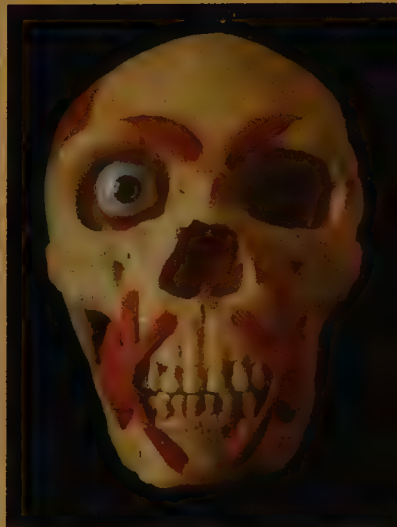
To reconstruct an extinct hominid, the collaborating artist and scientist first make a urethane cast of a skull and jaw. In this example, the artist Viktor Deak and the physical anthropologist Gary J. Sawyer base their reconstruction on a 400,000-year-old skull excavated from the Spanish site of Atapuerca, a fossil some have classified as *Homo heidelbergensis*. With data from dissections of present-day animals and humans—which they and others have conducted—they meticulously rebuild layers of muscles, glands, and other tissue onto a cast of the skull, using carefully measured strips of modeling clay. The technique is known as “dissection in reverse.”



Cast of the fossil, supplied by the excavators, is the starting point for the reconstruction. A silicone rubber mold is made from it, and a new urethane cast is produced.



Missing sections of the skull are reconstructed out of an epoxy compound, and any distortions are corrected (often by comparing the right and left sides).



Deepest muscle layers are sculpted in clay based on modern primate anatomy. One glass eye is set in position, with its surrounding musculature.

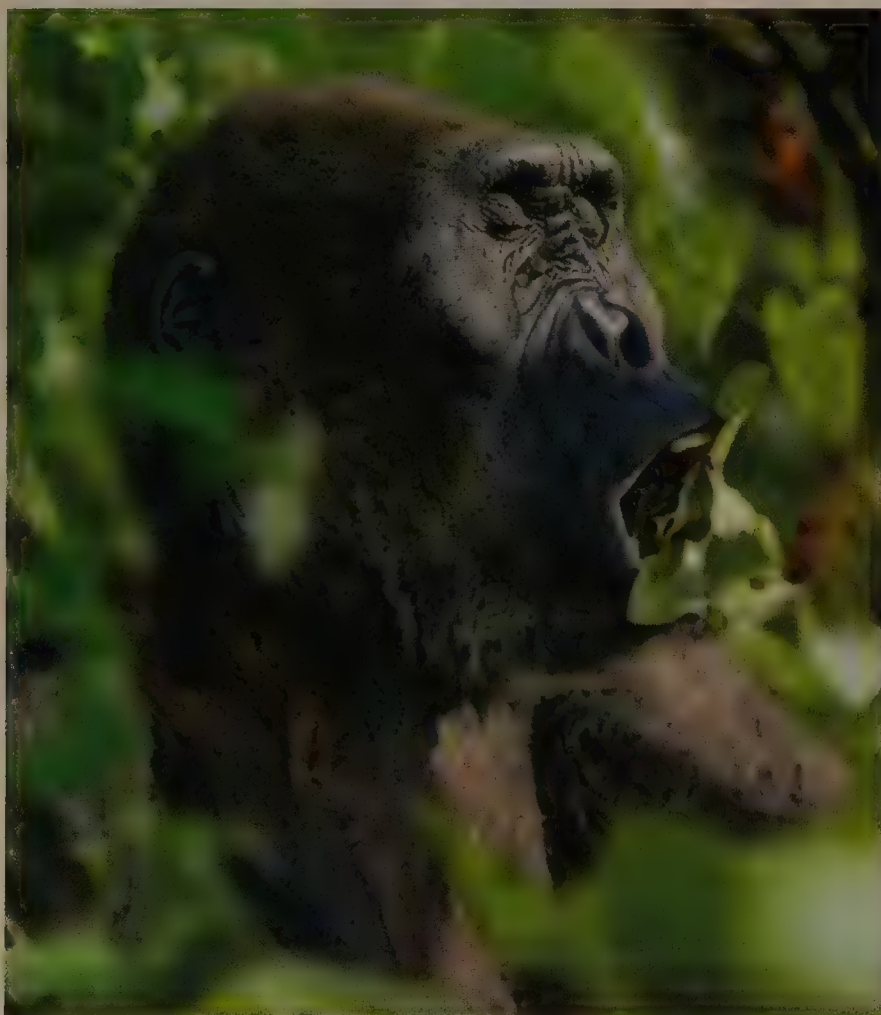
1856, a find that brought the term “caveman” into popular culture.

Beginning in 1858, when rich prehistoric deposits were discovered at Brixham Cave at Torquay, in Devon, England, the archaeologist William Pengelly developed revolutionary new techniques for conducting excavations. His systematic work at Brixham and nearby Kent’s Cavern over the next two decades yielded tens of thousands of

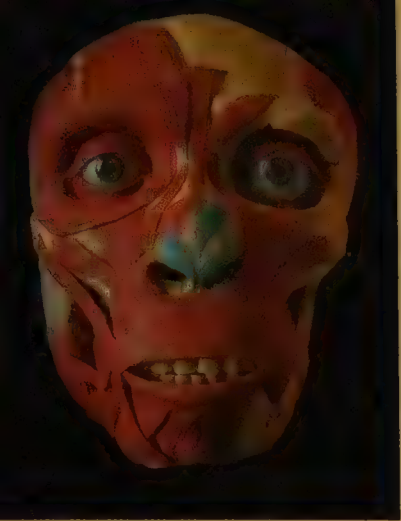
fossil animal bones and early human artifacts, and established their association in time.

Charles Darwin’s book *On the Origin of Species* shook the world in 1859 with its one-two punch: evolution by natural selection, coupled with the immensity of geologic time. The impact was seismic, but even before the book appeared, discoveries that ancient humans had lived with extinct mammoths and rhinoceroses in Britain had caused many to question traditional beliefs about human origins. In 1851 the art critic John Ruskin had lamented in a letter to a friend that his trust in biblical authority was being daily eroded by “those dreadful [geologists’] hammers.” “I hear the clink of them at the end of every cadence of the Bible verses,” he wrote. Now cavemen began to challenge Adam and Eve as primal ancestors in the popular imagination.

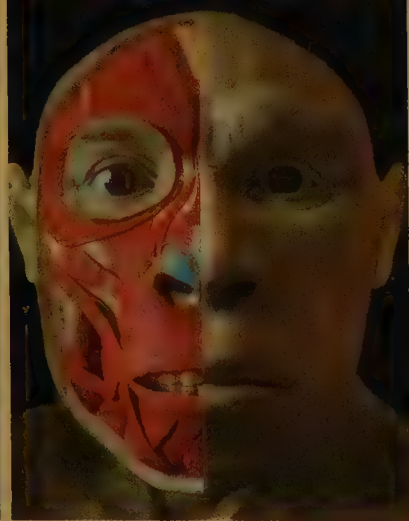
It turned out that some of the ancient “cavemen” were fine artists. In 1879 the first-known painted cave was accidentally discovered at Altamira, Spain; its images of extinct aurochs, bison, and horses stunned both the art and scientific worlds. Only rarely, however, had the ancient artists portrayed



Hominid with large molar teeth, *Paranthropus robustus* (left) lived in southern Africa about 1.7 million years ago. Many fossil features, including those of the hip and thigh, attest that it was bipedal, and characteristics of the hands indicate that the animal may have been able to make and use stone tools. It was a member of a diverse group of hominids that disappeared from the fossil record by about a million years ago. Right: Adult males of the species *Ardipithecus ramidus* brandish branches to frighten off a rival band of hominids. The reconstruction is particularly speculative, because the species is still poorly known. Although a remarkably complete skeleton was discovered in Ethiopia in 1994, its condition is delicate, hampering its preparation and scientific description. The fossils date from 4.4 million years ago, making *A. ramidus* one of the earliest hominids discovered so far, but it is not considered ancestral to humans.



Shape and size of the nose are calculated from surrounding bone attachments, and both eyes are set in place. Sculpting of superficial facial muscles is completed.



Half of the face, further built up to represent fat and other tissue, is covered with clay "skin." Using molds, textures are impressed into the surface.



Silicone rubber mold is made of the entire reconstruction, and a new cast is created in urethane rubber. Skin tones are painted onto the finished cast.

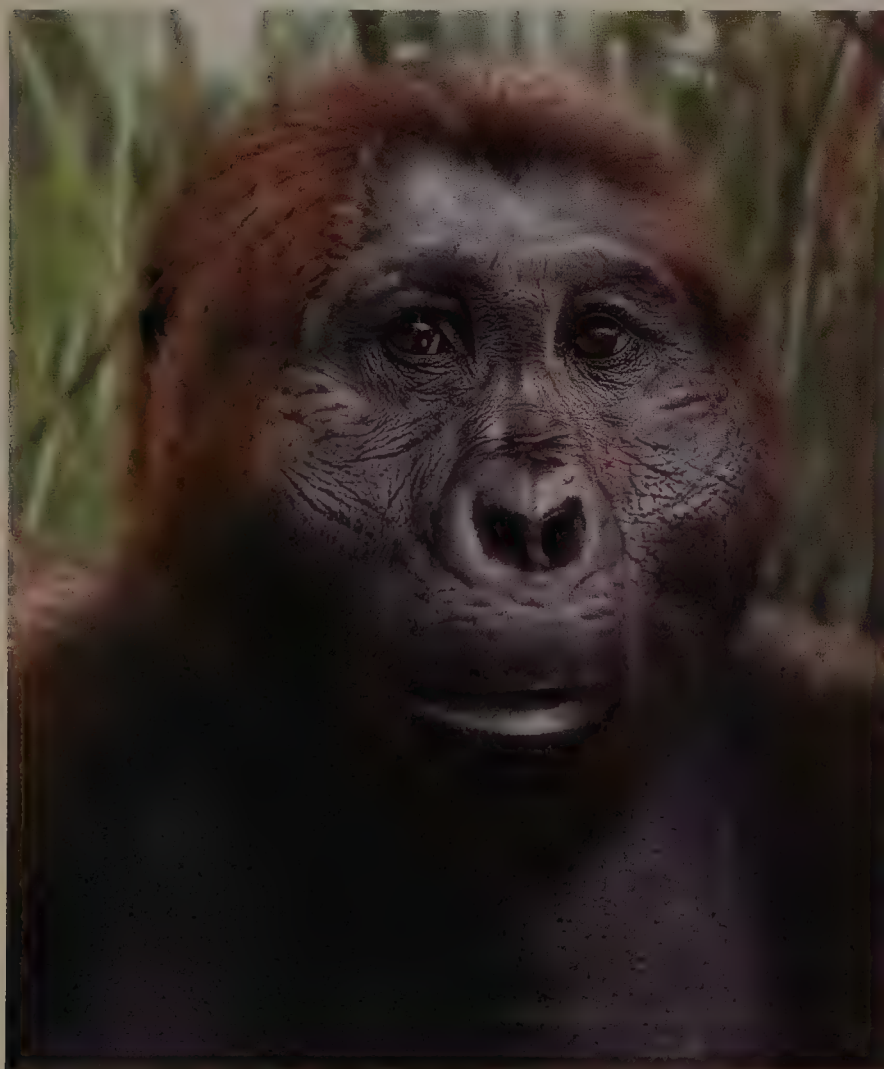


Hairs are individually punched into the skin, and finishing touches are applied. After the reconstruction is photographed, the image can be digitally enhanced.



themselves, and never with the sophisticated realism they had applied to other animals. That state of affairs cried out for modern artists to reconstruct the appearance of what became an expanding roster of extinct humans and near-humans. The nascent genre of paleoart, which had originated to visualize dinosaurs and other fossil animals, expanded to portray extinct humans as well.

John Lubbock, Darwin's informal (and only) student, commissioned some of the first paintings in the new genre. The scion of a banking family that owned much of the Kentish countryside surrounding Darwin's home, Lubbock decorated his indulgent father's mansion with a collection of primitive stone tools, ethnographic artifacts, glass-enclosed colonies of social insects, and eighteen watercolor paintings of early humans going about their daily lives. The paintings, which Lubbock sponsored during the 1870s, were the work of Ernest Griset, an outstanding natural-history illustrator whose anthropomorphic animal drawings often lent whimsy to the pages of the magazine *Punch*. Lubbock himself had coined the terms Paleolithic and Neolithic, meaning old and new stone ages, respectively, in his landmark book, *Pre-Historic Times*, which appeared in 1865.



The book also includes the earliest printed usage of the word "cave-man."

The undisputed king of the paleoartists was Charles R. Knight (1874–1953), who inspired all who came after him. The imperious paleontologist Henry Fairfield Osborn, president of the American Museum of Natural History in New York City from 1908 until 1933, hired the gifted young painter and teamed him with the museum's best anatomists and paleontologists. Together the teams created the most accurate and realistic reconstructions of ancient animals and early humans and near-humans that had ever been attempted. But Knight also relied on the caveman artists for his portrayals of Ice Age animals. When, in 1927, he visited the French painted caves to see the Ice Age artists' paintings firsthand, he had what he later described as "a distinct feeling of awe and admiration for the skill of the man who had painted and incised their curious outlines thousands of years ago."

One of today's preeminent paleoartists is Jay H. Matternes, based in Fairfax, Virginia, whose paintings are informed by his rich knowledge of primate anatomy and behavior. Knight often prepared for his painting of animals and cavemen by creating sculptures as reference points, carrying them onto the roof of his New York City studio at various times of day to observe where the shadows fell. Matternes has adopted the same technique. "Making a preliminary sculpture, even a quick one, to study light and shadow is a device frequently used by artists, and I have used it often," he writes.

One of the latest fruits of the vigorous tradition in paleoart is the creative collaboration between the physical anthropologist Gary J. Sawyer of the American Museum and the paleoartist Viktor Deak. (A selection of their depictions of our early relatives accompanies this article.) In their collaboration

Paranthropus boisei was a hominid with huge molars backed by powerful jaw muscles, inspiring the nickname "Nutcracker man" when the paleoanthropologist Mary Leakey discovered the first cranium of the species at Olduvai Gorge, Tanzania, in 1959. *P. boisei*, which dates from 1.8 million years ago, may have made some of the earliest crude stone tools, also found at Olduvai, but the fossils and tools are not firmly linked. Additional finds of *P. boisei* fossils have come from deposits near Kenya's Lake Turkana, which have also yielded early bones of the genus *Homo*, showing that the two hominids may have coexisted at the same time and place.



H. georgicus is named for fossils discovered at Dmanisi, a 1.8-million-year-old Georgian site in the lower Caucasus Mountains. The five crania and four jawbones unearthed there since 1991 represent the earliest firm evidence of a hominid that lived outside Africa. Its brain was small (between 600 and 700 cubic centimeters) compared to that of modern humans (which averages 1,350 cubic centimeters). The fossils were discovered in association with crude stone choppers and scrapers.

Sawyer and Deak also make sculptural busts of the ancient hominids, reflecting their knowledge of anatomy as well as clues from muscle attachments that occur in the fossil bones. Superficial features of hair and skin are partly a matter of guesswork, based on the appearance of modern humans and apes. Deak then photographs the busts, and may finally retouch the images digitally on a computer. [See "Dissection in Reverse," pages 24 and 25]

Both Sawyer and Deak had a childhood obsession with prehistoric humans and near-humans. Sawyer, a New Jersey native, was inspired by Knight's classic murals of dinosaurs, mammoths, and cavemen at the American Museum. Deak grew

up in a leafy, suburban Connecticut town that may seem an unlikely place to dream about living the life of Neanderthals. In 1991, however, at age fourteen, he viewed a *National Geographic* television program in a science class, which showed how the paleo-artist John Gurche sculpted a reconstruction of the hominid *Australopithecus afarensis*. "I was bitten by the bug," Deak recalls. "I knew immediately that I wanted to do what he did. . . . I see myself in these people, living thousands of years ago. I'm haunted by going back in time."

As the young Deak sketched fantasies of the remote past, he did not yet realize that he would need a scientific accomplice to discipline and focus his talents. When he was twenty-six, however,



Adolescent *H. ergaster* searches through swamp grass for food. The reconstruction is based on the well-preserved skeleton, found in northern Kenya, of a nine-year-old male. Known as "Nariokotome boy" (or "Turkana boy"), this individual lived 1.6 million years ago. He was of slender build with essentially modern-human proportions; when mature, he would have stood about six feet tall. Some consider *H. ergaster* the earliest fossil hominid that can properly be called human.

he met Sawyer, who was looking at the time for an artist to work with him on reconstructions of early humans. Their partnership exemplifies a long tradition of cross-fertilization between knowledge and skill, observation and vision.

In Darwin's day, people asked, "Where is the missing link?" Today, as previously unknown varieties of humans and near-humans continue to be identified, keeping up with the pace of discovery is a continual challenge. There are so many "missing links" that paleoanthropologists don't know what to do with them all. In place of the lineal tree trunk familiar to paleoartists until the mid-1960s, paleoanthropologists have since adopted a complex branching bush that reflects the fact that several kinds of humans lived on Earth at the same time and in some of the same places.

Many more species and fossils are known today than ever before, and new polyester resins, rubbers, and plastics give the paleoartist finer tools that make it possible to render ever greater accuracy of form. Furthermore, today's paleoanthropologists can

borrow the computer techniques of forensic medicine for analyzing data, creating sections of fossils through virtually any plane, or restoring the original shape of skulls that have been crushed or distorted by geological pressures. Texture, hair color, and skin are still matters of artistic interpretation, though work with ancient DNA may eventually shed light on those areas, too.

The best artist-scientist teams attempt to keep their imaginations in check, and treat the emerging likeness of a prehistoric face as a puzzle to be solved, according to strict rules of the game. As Gurche puts it, referring to an 8-million-year-old fossil ape discovered in Greece in 1990:

The final form of the animal is often a surprise—I try not to let any preconceptions guide me. I didn't expect *Ouranopithecus* to look as gorilla-like as it does, for example, but when I followed the process I've developed from great-ape facial dissection, that's just the way it came out.

We humans seem incapable of gazing, Hamlet-like, at a bit of skull or jawbone without trying to conjure up an image of how its owner appeared in life—and how similar or different was the appearance of its face from our own. Some of the homes of royal or wealthy European families house impressive galleries of ancestral portraits that go back ten or twenty generations, but most of us count ourselves fortunate to have a faded photo of our great-grandparents. And yet, in each generation, a few talented anthropologists, anatomists, and paleoartists—eternally optimistic—combine their skills in the attempt to show us all what our ancestors looked like, a hundred thousand generations ago. □

The images by Viktor Deak and Gary J. Sawyer that accompany this essay are used with the kind permission of Nèvraumont Publishing Company, from the forthcoming book, The Last Human: A Guide to Twenty-two Species of Extinct Humans, created by G. J. Sawyer and Viktor Deak, and produced by Nèvraumont Publishing Company, with a text by Esteban Sarmiento, G.J. Sawyer, and Richard Milner and contributions by Donald C. Johanson, Meave Leakey, and Ian Tattersall. The book is being published this month by Yale University Press. Many of the portraits have also been incorporated in the new hall of human origins at the American Museum of Natural History in New York City, scheduled to open to the public this February.

Reconstruction of a Neanderthal (*H. neanderthalensis*) is based on a 50,000-year-old skull found at La Ferrassie, a rockshelter in the Dordogne region of France. The site yielded the intentionally buried remains of eight individuals. Although Neanderthals had brains as large as those of modern humans (*H. sapiens*), many scholars believe the two lineages parted ways more than 500,000 years ago.



Eight Arms, With Attitude

Octopuses count playfulness, personality, and practical intelligence among their leading character traits.

By Jennifer A. Mather

Twenty-five years ago, when I started my fieldwork on the behavior of juvenile common octopuses in the azure waters of Bermuda, I expected all my subjects to be much the same. I assumed their activities would be fairly limited; individuals would hunt, rest, and avoid predators, all in roughly the same way. In fact, I learned, their behavior is quite complex and variable. I watched as they carefully chose rocky crevices for their dens and blockaded the entrances with piles of rocks. I observed them navigate complicated routes across the sea bottom to and from their hunting grounds. But I was most intrigued to discover that individual octopuses are very different from one another.

I could swear, for instance, that octopus number 45 never left its crevice—except that the discarded shells of clams, crabs, and snails kept appearing in front of the crevice. It must have been making secret hunting forays when my back was turned. By contrast, octopus number 26 was anything but shy. One afternoon I watched it as I floated in the shallow Bermuda water, hanging on to a rocky outcrop. The little octopus peered back at me from inside its den for some time, then suddenly jetted three or four feet directly toward me and landed on my dive glove. After about a minute of exploring, it must have decided the glove didn't taste good, and slowly jetted back home. I was hooked.

Around the same time, Roland C. Anderson, a marine biologist at the Seattle Aquarium who has since become my frequent collaborator, noticed that aquarium workers gave names to only three kinds of animals in their care: seals, sea otters, and giant Pacific octopuses. The workers named the octopuses for their distinctive behaviors. Leisure Suit Larry, for instance, was all arms. He touched and groped his keepers so often that had he been a person, he would have been cited for inappropriate behavior. Emily Dickinson, by contrast, hid permanently behind the artificial backdrop of her display tank,

so retiring that eventually she had to be replaced by a more active octopus for aquarium visitors to watch. Then there was Lucretia McEvil, whose caretakers were afraid to approach her, and who ripped up the interior of her tank. All those “characters” set me to thinking about whether octopuses might just have something like human personality.

Twenty-five years ago it was hard to know what



to expect of octopus behavior: the creatures had seldom been studied, and when they had, it was mostly in captivity. Furthermore, they are invertebrate mollusks, and so they are evolutionarily distant from vertebrates; it would have been hard to justify extrapolating the significance of their activities from the well-studied behaviors of mammals and birds.

Most mollusks are clams or snails that hide within hard shells and have little brainpower. But cuttlefish, octopuses, and squid (which along with nautilus make up the cephalopod mollusks) are nothing like their shell-bound relatives. Evolution led them to lose their protective shells, but what they gained was far more interesting: dexterous, sucker-lined arms; ever-changing camouflage skin; complex eyes; and remarkably well-developed brains and nervous systems. The 289 known species of octopus range in size from the one-ounce Atlantic pygmy octopus, *Octopus joubini*, to the giant Pacific octopus, *Enteroctopus dofleini*, which can weigh more than a hundred pounds. They are all ocean-dwellers, and, though the group is distributed from the

poles to the tropics, octopuses are reclusive beasts; individuals are hard to find, let alone study.

The intelligence of octopuses has long been noted, and to some extent studied. But in recent years, research by myself and others into their personalities, play, and problem-solving skills has both added to and elaborated the list of their remarkable attributes. They turn out to be uncannily familiar creatures, not nearly as unlike you and me as one might expect—given their startlingly different physiques and the 1.2 billion years of evolution that separate us from these eight-armed marvels of the sea.

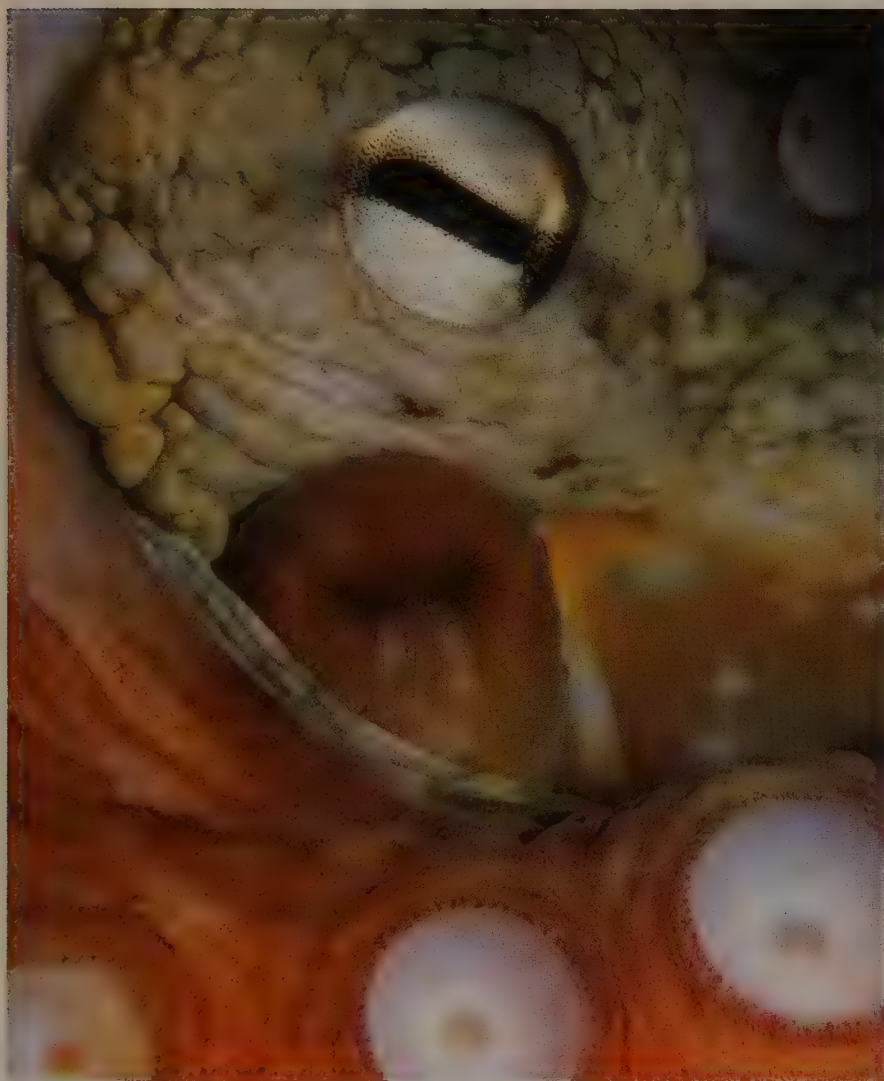
Personality is hard to define, but one can begin to describe it as a unique pattern of individual behavior that remains consistent over time and in a variety of circumstances. I've adopted the model that developmental psychologists have applied to study the behavior of children. Psychologists begin with the idea of "temperament," or behavioral tendencies genetically pro-



Giant Pacific octopus swims by jet propulsion. The animal draws water into its mantle, the bulbous sack that contains its internal organs, then expels the water through its funnel, a tube-like appendage protruding from the mantle. For many years giant Pacific octopuses, along with seals and sea otters, were the only animals given names by the workers at the Seattle Aquarium. That prompted the author and her collaborator to explore the possibility that octopuses have personalities.

grammed before birth. After birth the environment shapes an individual's temperament to give rise to an adult personality.

Many people assume that only human beings have personalities. Yet in the past fifteen years or so a number of investigators have reported evidence of personality in animals as diverse as guppies, hyenas, and rhesus monkeys. To pin down what can be a notoriously slippery concept, they have identified a number of personality traits, or "dimensions,"



Eye-to-eye with a common octopus, the camera records a view that few fish would survive. The octopus eye (circle with dark slit at top of the image), like that of other cephalopods, is a remarkable example of convergent evolution; it has many of the same parts as the vertebrate eye, including a cornea, iris, lens, and retina, despite more than 1.2 billion years of independent evolution.

such as activity, aggression, curiosity, and sociability. Many animals, including people, can be rated along each of those dimensions, and an individual's rating along one dimension can vary more or less independently of its ratings along the others.

Could a combination of differences in genes and life experience—personality—have made individual octopuses behave so differently from one another? Our experiences led Anderson and me to think so. We didn't expect to discover a sociability

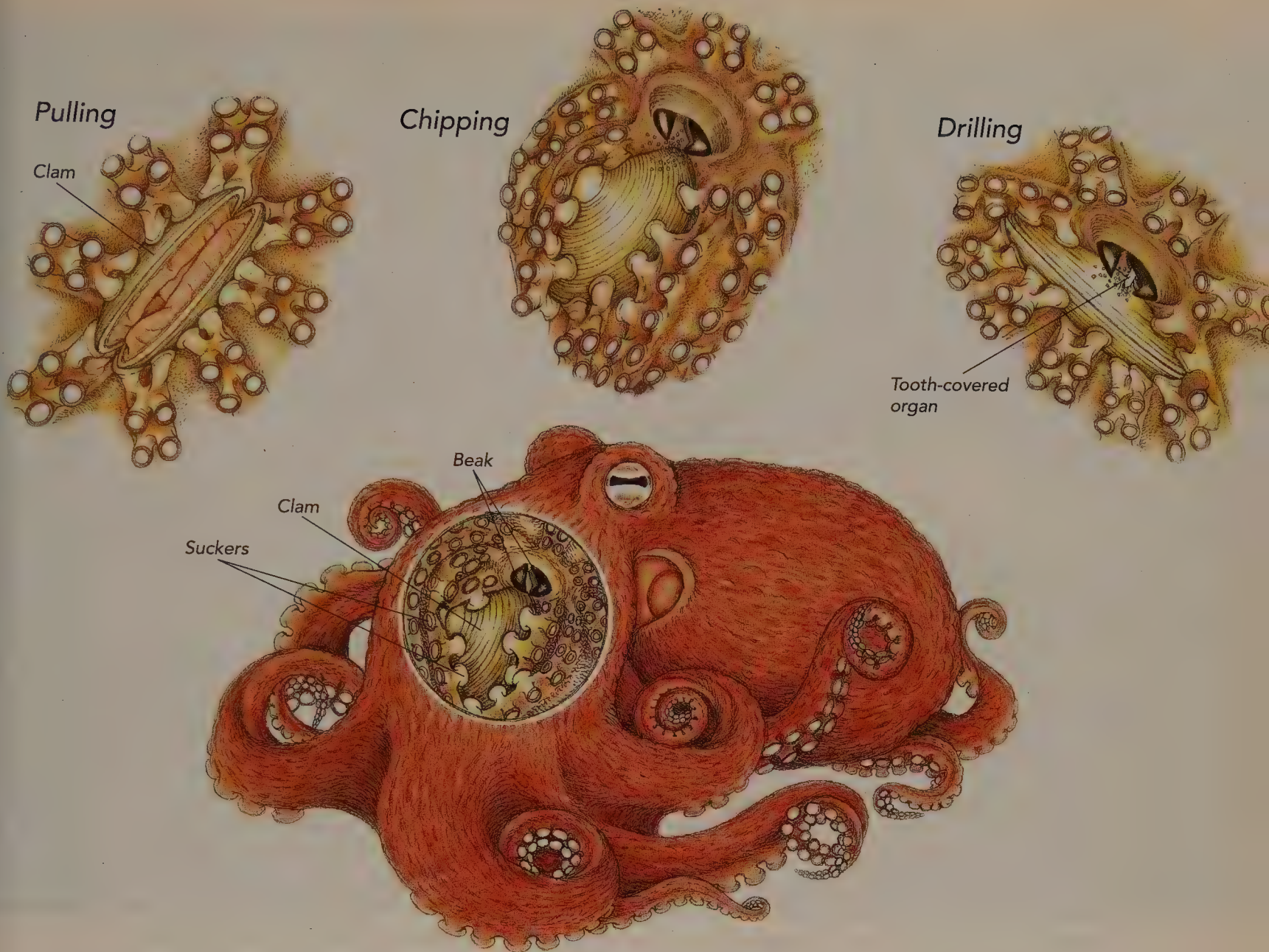
dimension because octopuses lead solitary lives, but we thought we might find differences along such dimensions as activity or aggression.

We gave "personality tests" to forty-four red octopuses (*Octopus rubescens*), natives of the West Coast of North America that weigh as much as a pound. We exposed each animal to three test conditions, seven times each, during a two-week period. We measured and recorded their responses when we opened the tank lid, when we touched them with a brush, and when we fed them a crab. The brush prompted the greatest variety of responses. Some octopuses grabbed it, stood their ground, and inflated their mantle to look bigger. Others jetted to the opposite end of the tank, leaving a cloud of obscuring dark ink in their wake. Individuals gave the same responses to the tests even after being exposed to them several times.

In all, the forty-four octopuses responded to the three tests with nineteen distinct behaviors. Statistical analysis enabled us to group the nineteen behaviors and place them along three personality dimensions: activity (how much the octopus moved around), reactivity (how strongly it reacted to the stimuli), and avoidance (how much it kept out of our way). An octopus could vary on all three dimensions independently. For example, among highly avoidant octopuses, which tended to remain in their dens during testing, some were extremely reactive, shrinking at the first sign of the brush. Others were not reactive at all, practically ignoring the brush. (By extension, Leisure Suit Larry, the touchy-feely giant Pacific octopus, would have rated high on activity and low on avoidance.)

So do octopuses have personality? Our answer is a qualified "yes." Because we didn't try to change their personalities by manipulating their experiences, we couldn't rule out the possibility that their behavioral variations might have been genetically preprogrammed. But given the octopus's legendary intelligence, behavioral flexibility, and learning ability, such preprogramming seems unlikely.

How much of the behavioral differences among individual octopuses is inherited, and how much is learned? For his master's thesis, David L. Sinn, now a zoologist at the University of Tasmania in Hobart, raised laboratory-born California two-spot octopuses (*Octopus bimaculoides*) in small isolation chambers and gave juveniles the same three tests Anderson and I gave our red octopuses. The genetic effects were clear. Octopuses that shared at least a mother (female octopuses mate several times with any available male, so paternity was all but impossible to determine) reacted to the three



Cutaway view of a giant Pacific octopus (above) shows how it manipulates a clam it is about to eat. Octopuses have several techniques for breaking into clam shells. They can pull the shell halves apart with their arms and suckers (top left). They can chip with their beaks (top middle). Or they can drill a hole by alternately secreting acid and scraping with a tooth-covered organ in the mouth (top right). If an octopus drills or chips, it secretes a paralytic toxin into the shell to weaken the muscles holding the shell halves together. Octopuses are excellent problem-solvers: which technique an octopus chooses depends on the species of clam, the thickness of the shell, and the strength of the clam's muscles.

tests more similarly than octopuses from different broods. Intriguingly, Sinn also discovered that as the animals matured, their responses to the tests changed in a predictable way.

Sinn did not raise his subjects to maturity, so no one knows whether youthful experiences might have added a layer to the octopuses' temperaments to yield true adult personalities. It's too bad—it would be fascinating to know whether octopuses' differing experiences when young would result in differing adult personalities. Was Lucretia McEvil's destructiveness, for instance, the result of a "bad childhood"?

Another question about octopus personality is whether it has evolutionary benefits or drawbacks. The only scientific clue comes from Sinn's doctoral

work, which showed that squid, too, vary along the personality dimensions of avoidance, activity, and reactivity. Shy female southern bobtail squid, Sinn found, mate with males that are shy, bold, or anything in between along the avoidance dimension. But bold females tend to reject shy males. Score one for the survival of the boldest. Sinn also found, however, that shy females are more successful than bold females at hatching their broods of eggs. No obvious pattern emerges, but personality clearly does affect survival and reproductive fitness.

Evidence for the octopus's intelligence begins with its anatomy. Intelligent animals typically have large brains, and octopuses' brains are large for their body size compared to those of other ani-

mals—larger than fishes' brains and, proportionally, as large as those of some birds and perhaps some mammals. Moreover, three-fifths of an octopus's neurons aren't even in its brain. Instead, they are divided among its eight arms to coordinate the arms' remarkable flexibility. The big brain itself is mostly dedicated to learning, planning, and coordinating actions with stimuli.

Broadly defined, intelligence is the measure of an animal's ability to acquire information from its environment and to change its behavior in response—in short, to learn. The octopus's behavioral repertoire has few fixed, preprogrammed responses, and it can respond to a given stimulus in a great variety of ways; those are both hallmarks of intelligence and learning. The sea slug, by contrast, has only a limited palette of reflexive responses, no matter what the stimulus. In one particularly vivid demonstration, published in 1970, the biologist William R.A. Muntz showed that octopuses could learn to tell complex visual figures apart by forming a new rule for each for each new set of figures. He concluded that octopuses aren't merely able to learn; they can also learn what to learn.

Anderson and I became interested in how octopuses apply their intelligence to predation. After capturing a clam, an octopus must break through the hard shell to get to the meat inside. To do so, it can deploy a veritable built-in Swiss Army knife of tools [see illustration on preceding page]. It can pull the shell's halves apart with its arms and suckers, chip at the shell's edge with its beak, or drill a tiny hole in the shell by alternately secreting acid to dissolve it and scraping at it with one of two tooth-covered organs in its mouth. (Which of the two organs it uses remains subject to debate.) If the octopus breaches the shell by chipping or drilling, it secretes a paralytic toxin into the clam's muscles so that it can more easily pull the shell halves apart—and then it's dinnertime.

We discovered that giant Pacific octopuses apply differing techniques to various clam species: they break fragile mussel shells, probably while pulling on them; they pull apart the stronger Manila clams; and they drill or chip at the strongest clams, the littlenecks. We placed individuals of each species on a device of our own design (which we darkly called the "clam rack"), and measured how much force it took to overcome the clam's muscles and pull the shell halves apart. Intriguingly, octopuses ate plenty of weak-muscled mussels when they had to open dinner by themselves, but they gobbled up littleneck clams—all but ignoring the mussels—when we offered all three species on the half

shell. Maybe the mussels were less tasty but easier to get at than the littlenecks.

Octopuses conduct the business of breaking into clams with the clams near their mouths, which are under their arms and so out of sight. There they dexterously manipulate the clams into position by touch. To pull clam shells apart, an octopus holds it with the umbo (the bump near the shell's hinge) toward its mouth. But if it chooses to chip at the shells' edge, it moves the clam's "sides," where the muscle insertions are, toward its mouth. And when it drills, it turns the broad side of the shell toward its mouth.

Giant Pacific octopuses usually drill through the center of a clam's shell into its heart. But they must learn where to drill the holes. Anderson found that juveniles drill their first few holes randomly on the shell, but they soon master the art of drilling near the heart or the muscles that hold the shell halves together. Either place is a good target for injecting paralytic toxin.

We were curious about what octopuses would do with artificially strong Manila clams, whose shells they usually just pull apart. We gave each octopus Manila clams held together with strong wire. The octopuses simply switched tactics to drilling or chipping, thereby confirming the numerous studies such as Muntz's that had shown they are good problem-solvers. They can weigh effort against food reward, flexibly switch penetration tactics, and orient the clam to penetrate its shell most effectively—all good uses of intelligence, indeed.

After investigating a few octopus problem-solving skills, Anderson and I turned our attention to two less-studied categories of behavior that are also linked to intelligence: exploration and play. Philosophers and psychologists have debated for centuries about the nature of play, where it comes from, and what purpose it serves. When animals play with objects, their explorations move from "What does this object do?" to "What can I do with this object?"

Gordon M. Burghardt, a biologist at the University of Tennessee in Knoxville, recently offered a clear and useful definition of play in healthy animals. Play, he writes, is made up of voluntary, incomplete, repeated fragments of activity that have no obvious purpose, and which are often exaggerated and out of normal context. Some scholars still maintain that people are the only animals that truly



Giant Pacific octopus feeds on a dead spiny dogfish. Octopuses can instantaneously change color and texture, often to camouflage themselves. Giant Pacific octopuses can change from a "relaxed" rusty red to gray, pale beige, coral, orange, red, or any mottled variation in between. Certain colors may indicate an octopus's internal state: the scarlet color of the octopus shown here could indicate stress, possibly triggered by the camera's flash. Or it could be a simple, automatic reaction to the burst of light.

play. But dog owners know that when their companion lowers its front end and raises its hind end, tail wagging, it has no purpose but to communicate that the next set of interactions should be just for fun. Crows slip down a playground slide over and over, or grasp a clothesline in their claws and spin round and round like a pinwheel, calling "Wheee" the whole time. Those behaviors clearly conform to Burghardt's definition, and other examples are documented in many animals, including dolphins, lab rats, and river otters.

Would an octopus play if given the chance? We decided to find out. Animals are more likely to play when they are satiated and secure, without any threat from predators. An aquarium tank is such an environment. There we presented eight well-fed giant Pacific octopuses with plastic pill bottles containing enough water that they floated

at the surface of the tank. The octopuses followed a fairly predictable behavioral sequence. First, they grasped a pill bottle with one or more of their arms and explored it with their suckers. Then they pulled it to their mouths, and sometimes bit it with their parrotlike beaks. Gradually, both within each trial, and by the end of all ten trials, most of them lost interest in the bottle.

But two of the octopuses independently did something very different in the later trials. Like most aquariums, their tanks had water-circulation systems; water entered the tank at one end and exited at the other. While sitting near the outflow, each animal released the bottle it had been holding and jetted water through its funnel, sending the bottle against the gentle current to the inflow end of its tank. (A funnel is a tubelike appendage that an octopus uses for breathing and for jetting through

the water [see photograph on pages 30–31].) When the bottles returned on the current, the octopuses jetted them upstream again, repeating the process more than twenty times. Anderson, who had been skeptical that octopuses play, phoned me excitedly after watching the first playful octopus and said, “It’s like she’s bouncing a ball!”

In vertebrates, some kinds of play have benefits as well as simply being fun. They strengthen and define social relationships, as in the roughhousing of canines. Or they give young animals the chance to hone fragmentary actions into polished sequences, as when a kitten plays with a mouse to “practice”



Play in octopuses has been documented experimentally, but remains controversial. After investigating and habituating to blocks for several days, common octopuses engaged in play or playlike behavior, passing the blocks from arm to arm, towing the blocks, or repeatedly pushing and pulling them back and forth. The octopus pictured here exploring a block with her mouth was among the most playful in the experiment. In another experiment, giant Pacific octopuses sent buoyant pill bottles circling repeatedly around their tanks.

capturing prey in the future. Skeptics often dismiss play by nonhuman animals as functional, and thus in violation of Burghardt’s definition that it have no obvious purpose.

But octopuses don’t have social relationships—they’re solitary creatures, except when they mate. And as for the argument that only the young play because only they need to practice their skills, Michael J. Kuba, a former graduate student of mine now at Hebrew University in Jerusalem, recently showed that adult common octopuses also engage in playlike behavior. They passed a plastic block from arm to arm or pulled it along when they swam just as often as the young did. Still, in our view, octopus play is neither as extensive as it is in mammals, nor as potentially adaptive. It may simply be a sign of an active mind at work.

Octopuses have personalities. They learn. They solve problems. They play. Does all that add up to a simple form of consciousness? The suggestion is even more contentious than the ideas that octopuses play or have personalities. Just defining consciousness is tricky; one general definition is that an animal with primary consciousness—a dog, for instance—is aware of the complexity of a given circumstance as well as its role there and its decision-making options. Higher-order consciousness has more stringent criteria: using language, being able to report on the content of one’s thoughts, being able to think about thinking. Only people and perhaps chimpanzees exhibit that exalted form of consciousness.

But how could one tell whether octopuses have some form of primary consciousness? Some theorists say it is enough to show complex and flexible behavior, such as the octopus’s clam-opening tactics. Others say an animal must be able to shift its attention from one set of stimuli to another, making decisions in rapidly changing conditions. Octopuses meet that criterion in their varied responses to a predator: they can flash unpredictable changes in pattern and color, jet off in an unexpected direction to escape, or squirt out ink to form a smoke screen.

Still other theorists argue that conscious animals build a complex, multidimensional set of internal impressions about the world on the basis of their sensory perceptions. For example, the human mind constructs a three-dimensional image of objects from the two-dimensional array of stimuli that arrive at the retina. Additional study of how octopuses analyze visual shapes might show whether they meet that criterion, too. Or perhaps a conscious animal must have a concept of self. What do octopuses see when they look in a mirror? Answering that question will be our next research project.

It will be hard to say for sure whether octopuses possess consciousness in some simple form. But from what biologists already know about them, there’s no denying they are some smart suckers. □

AS HEARD ON PAUL HARVEY NEWS

New advanced portable heater can cut your heating bill up to 50%

Heats a large room in minutes with even heat wall to wall and floor to ceiling

Does not get hot, cannot start a fire and will not reduce humidity or oxygen

Never be cold again

A new advanced quartz infrared portable heater, the EdenPURE®, can cut your heating bills by up to 50%.

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Q. What is the origin of this amazing heating element in the EdenPURE®?

A. This advanced heating element was discovered accidentally by a man named John Jones.

Q. What advantages does infrared quartz tube heating source have over other heating source products?

A. John Jones designed his heating source around the three most important consumer benefits: economy, comfort, and safety.

In the EdenPURE® system, electricity is used to generate infrared light which, in turn, creates a



Cannot start a fire; a child or animal can touch or sit on it without harm



very safe heat.

After a great deal of research and development, very efficient infrared heat chambers were developed that utilize three unique patented solid copper heat exchangers in one EdenPURE® heater.

Q. How can a person cut their heating bill by up to 50% with the EdenPURE®?

A. The EdenPURE® will heat a room in minutes. Therefore, you can turn the heat down in your house to as low as 50 degrees, but the room you are occupying, which has the EdenPURE®, will be warm and comfortable. The EdenPURE® is portable. When you move to another room, it will quickly heat that room also. This can drastically cut heating bills, in some instances, by up to 50%.

The EdenPURE® comes

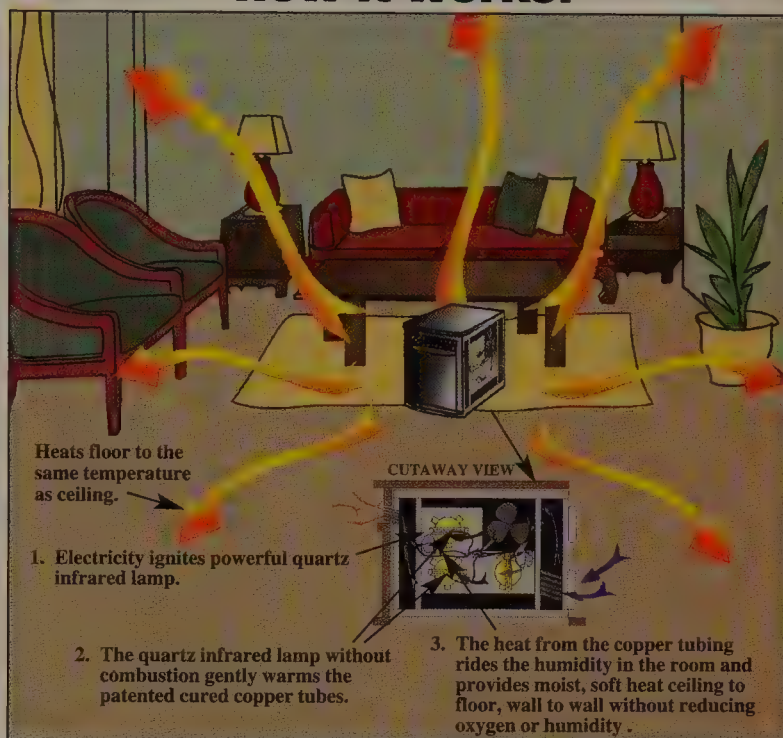
in 2 models. Model 500 heats a room up to 300 square feet and Model 1000 heats a room up to 1,000 square feet.

End of interview.

The EdenPURE® will pay for itself in weeks. It will put a great deal of extra money in a users pocket. Because of today's spiraling gas, oil, propane, and other energy costs, the EdenPURE® will provide even greater savings as the time goes by.

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Family Ties

Unexpected social behavior in an improbable arachnid, the whip spider

By Linda S. Rayor

If you're a fan of the Harry Potter films, you've seen an amblypygid. The most recent cinematic installment of the series, *Harry Potter and the Goblet of Fire*, showed an improbable creature with a flat body, spiny "arms," and incredibly long, flailing "whips" that was ultimately killed in a class demonstration of the Avada Kedavra curse. (In the book, a spider was sacrificed.) Most viewers probably assumed the creature was a figment of the director's imagination. Not so. In fact, with minimal digitization and color enhancement, an amblypygid stole the scene.

Amblypygids—commonly called whip spiders or tailless whip scorpions—are neither spiders nor scorpions. Nevertheless, as their appearance suggests, they are arachnids. Spiders and uropygids (also called vinegaroons) are their closest relatives; other arachnids, including harvestmen, pseudoscorpions, scorpions, and solfugids (also known as wind scorpions) share similar characteristics. Like them, amblypygids have eight legs, two main body parts (an

abdomen and a combined head and thorax known as a cephalothorax), and a pair of spiky appendages known as pedipalps or simply palps—situated on either side of their mouthparts [see upper photograph on page 40].

Add up those discordant parts, include their first pair of legs, or "whips," and amblypygids seem rather improbable. As it turns out, their behavior might also strike some as strange. My research suggests that the animals, long thought to be solitary and aggressive to members of the same species, are surprisingly social. Mothers and siblings remain in close, interactive groups for almost a year before the young reach sexual maturity. If my recent studies are any indication, the creatures warrant more attention than a cameo appearance on the big screen.

The first amblypygid I ever encountered in the wild loomed over me while I was visiting an outhouse in Costa Rica. The creatures often slip their flat bodies into



such places, where they can hide in narrow crevices during the day. At night they emerge to hunt, often on the trunks of trees or inside caves—or, as in my case, on an outhouse wall. A total of 136 species occur worldwide, primarily in the tropics, throughout Africa, India, Latin America, and Southeast Asia. They range in body length from an eighth of an inch to one and three-quarters inches. *Phrynus marginemaculatus*, a Florida native the size of a dime, and the slightly larger *Phrynus fuscimanus*, an inhabitant of the desert regions of

Arizona, are the only amblypygids indigenous to the United States.

An amblypygid's palps—the wide “arms” near their mouth—are long, covered in spines, and tipped with small stilettos. The palps can reach out to grab like a hand or to stab their arthropod prey like a talon. In many amblypygid species the adult males sport considerably longer palps than the females do. The male palps are often deployed in intense male-male contests, in which each male strikes rapidly at his opponent with open palps. Such a battle may be a

Newly-hatched whip spiders (*Phrynus parvulus*) cling to their mother's back in Costa Rica. They stay aboard and remain largely immobile for about a week after they hatch. If they happen to drop off, though, they do not survive, and their mom—about an inch long—may even eat them.





Female *Heterophrynus*, pictured here among leaf litter in southern Guyana, displays her palps, or "arms" near her mouth, with spines about a quarter of an inch long. Palps are formidable weapons for stabbing prey and fighting other whip spiders of both sexes.

way of assessing the size of competitors [see lower photograph on this page].

All aspects of an amblypygid's life center on the use of their delicate first pair of legs, which put the whip in the name *whip spider*. The whips are not used for walking; rather, they are covered with fine chemosensory and mechanosensory hairs that function much like an insect's antennae. The sensory hairs on the whips can distinguish a multitude of airborne odors—a rare ability in arachnids—or detect mechanical changes through touch or air currents. The whips are incredibly flexible and may be three to four times the length of the walking legs—as long as three feet in the larger species. Each whip comes with as many as 148 joints, which enables the animals to delicately explore 360 degrees around their bodies. It's no wonder the whips are constantly sweeping and probing their environment.

When something interesting comes along, the whips move accordingly. For example, my students and I have shown that if prey or, alternatively, a sibling, approaches from one side, the near-side whip moves faster than the far-side whip. A hunting amblypygid may even reach around a corner with its whip and gently touch potential prey, such as a cricket, so that it is led, unaware of the danger, toward the hunter. That keen technique is evidence that amblypygids may be among the smartest arachnids. Nicholas J. Strausfeld, a neuroanatomist at the University of Arizona in Tucson, demonstrated that amblypygids have the largest mushroom body—an area of the brain associated with spatial memory and learning—of any of the arachnids.

Although they are fearsome predators, amblypygids are also solicitous lovers. Males court potential mates by stroking the females repeatedly

with their whips. Sometimes the male vibrates his own palps or gently nibbles on one of the palps of his mate. Even when not actively courting, a couple interacts intensely for several weeks, typically facing each other or sitting close together for the entire courtship period [see upper photograph on page 43].

The male amblypygid does not have a sex organ like a penis that can deliver sperm directly and internally to the female. Instead, he secretes a small white stalk and deposits a protein-covered sperm package into the stalk's clasps; the entire structure is known as

a spermatophore. The upright stalk is glued to the surface of the tree or rock where the couple has been courting. The male hopes to entice the female to take up the sperm package. Each time she does, a spermatophore stalk is left behind, and so by counting stalks, one can tally the number of times a couple has mated. I have counted more than nine stalks left by a single male during a two-week period when his mate was receptive.

Following courtship, the male and female move



Two males (*P. parvulus*) grapple for territorial supremacy on a tree in the lowland forests of Costa Rica.

apart and seemingly have little more to do with each other. The female deposits her eggs in a brood pouch on her abdomen. After roughly ninety days for smaller species and 120 days for larger ones, the eggs hatch; even the shorter gestation time is surprisingly long for an arachnid. Like young scorpions, vinegaroons, and wolf spiders, newly hatched amblypygids climb onto their mother's back for about a week [see photograph on pages 38–39]. During that stage, they do not eat. Their hard exoskeletons do not sclerotize, or darken and harden, and so they remain a vivid lime green until they molt, climb off their mothers back, and begin catching prey for themselves.

The traditional thinking has been that amblypygids lead entirely solitary lives. In fact, when I first began my research on them, I was told that a mother would kill her own young if they remained with her after the first week. So, given the reputation of adult amblypygids for aggression, imagine my surprise when I first observed their social interactions. Now my students and I, working with captive mother-offspring groups, have shown that the animals lead highly complex social lives.

One morning, as I watched a *P. marginemaculatus* mother with her three-week-old young, I observed an amazing sight: The mother walked directly over to a group of ten closely grouped offspring and gently stroked them with her whips. The young moved to surround and orient to her and stroked her in return, touching her whips, palps, and legs. Over a period of about four minutes, the mother made individual contact with seven out of the ten youngsters. Although the young had initially been sitting close together, slowly waving their whips, their whip movements quickened once their mother joined the group, so that most of the youngsters touched each other while she was with them.

Then the mother left the group of ten, and walked directly to a separate group of youngsters. She stroked them—and, as with the first group, they stroked her in turn—for about thirty seconds. Finally, she visited a third group and repeated the interaction for several minutes, before returning to sit in the middle of the first group. In each case, the young oriented towards

their mother and stroked her palps, whips, and legs with their whips. What amazed me about those interactions was that they appeared to indicate social bonding between a mother and her offspring.

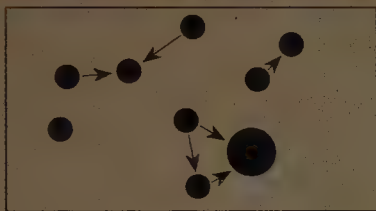
After watching that mother-offspring behavior in amazement, I set out to discover just how social the creatures might be. In the past five years my students and I have quantitatively documented



Mother *Damon diadema* (right) circles a thin “whip,” or modified leg, to stroke one of her young (left). The youngster is about four months old and measures three-eighths of an inch long. A second youngster is under the mother's left palp.

extensive social interactions in captive populations between mothers and offspring, and among siblings, in two amblypygid species: the Floridian *P. marginemaculatus* and the much larger *Damon diadema*, from Tanzania. The results are changing the view of amblypygids as solitary animals.

Why is this finding so exciting? Among arachnids, maternal care (or, in the case of some harvestmen species, paternal care) for the eggs and the newly emerged offspring is not uncommon. Yet arachnid social behavior, beyond the transient parental care of newborns, is extremely rare. Less than 0.1 percent of the almost 93,000 known arachnid species live in interactive social groups for extended periods. Along with the two amblypygid species I have studied—in which mothers and their offspring may remain together for nearly a year—only fifty-three



Family portrait of *D. diadema* includes an adult female (with a sheen because she has recently molted) and eight of her twenty-two offspring. Each animal is touching another, being touched, or has just been touched by a relative's whip. In the schematic diagram at left, each arrow points from the animal touching with its whip to the animal being touched. The young are about eight months old and will continue to interact peacefully with their mother and one another for three or four more months.

spider species, eleven scorpion species, three pseudo-scorpion species, and seven spider-mite species have been observed to live in social groups.

Sociality is broadly defined to include interactive groups whose members tolerate one another and associate beyond early development. The sociality of some groups is short-lived: in some spider groups the siblings remain together for a couple of instars after eating their mother, and young scorpions remain with their mother for part of their development. At the other end of the social spectrum are the complex societies of the highly social cobweb-weaving spiders, *Anelosimus eximius*, of Central and South America. They maintain group nurseries for their young in massive webs that house thousands of individuals.

For arachnids, the benefits of being social include having others help capture large prey, sharing prey once it is caught, and cooperatively constructing a retreat (which may be webs, burrows, or silk-covered lairs). Furthermore, the longer the youngsters have to grow and become better predators before becoming independent adults, the better their survival. Some investigators have suggested that unlike the

eusocial insects—ants, termites, many wasps, and some bees—which work together to increase the reproductive output of the colony, the few arachnid societies function primarily to increase the foraging success of the group's members.

In spite of the potential benefits of cooperation, mutual tolerance by arachnids of the same species is very rare. Why hasn't sociality evolved more often among them? Probably because most arachnids are predators that not only compete for prey but also can prey on each other. For example, the longer offspring remain with their mother, the greater their predatory capabilities and the greater their need for prey. As the young mature, the balance between cooperation and conflict, which is inherent in all social groups, becomes ever more precarious. By studying the rare arachnid species that live in amicable social family groups, biologists can pose ecological and evolutionary questions about the costs and benefits of group living.

Amblypygid social groups share many, though not all, traits of other groups of social arachnids. My students and I have observed seventeen *D. diadema* family groups for a year or more in captivity. In each

one, the mother amblypygid and her offspring have been peaceful and interactive. Their social relations are consistently friendly, with little aggression until the young begin to reach sexual maturity, at about twelve to fourteen months.

As they reach sexual maturity, however, the siblings become aggressive toward each other. My students and I find young adults with missing whips, damaged legs, or emaciated bodies (the last because the victims are forced to hide from aggressive males). At this age individuals are sometimes cannibalized, something we never see in younger animals. In the wild, the family groups would clearly disperse by the time the offspring are sexually mature. In some groups, the mother continues to interact with her youngsters throughout their development; in others, she leaves the group before she molts or mates again. It is the siblings that form the strongest social bonds [see photograph on opposite page].

The most obvious social trait in *D. diadema* is that the members of a family group stay close together, constantly touching and exploring each other and their surroundings with their whips. Typically, they form loosely connected groups, within which between three and twenty animals are in constant contact with some other family members. As the youngsters grow older and larger, they space themselves progressively farther apart, but remain within easy reach, separated by less than a whip length. Although there are always a few youngsters that move away from the group, most of them stay closely associated with other family members until sexual maturity. There is remarkably little aggression among the immature siblings. In a testy exchange, one youngster might open its palps or chase its sibling briefly, but we have seen none of the grappling or standoffs with wide-open palps and flicking whips that so characterize adult male conflicts.

Cannibalism, always a risk among arthropod predators, is extremely rare in the family groups. In contrast, when adult *Damon* are kept together, even in huge cages

with plenty of food, they spread themselves as far apart as they can (unless they happen to be courting), and cannibalism is common. My student Rachel E. Walsh has shown that when seven- to nine-month-old *D. diadema* are briefly removed from their families, then either reintroduced to their own group or placed within an unfamiliar group of the same age, they are more aggressive to the unfamiliar animals than to their own family members. Since all the animals in Walsh's experiment were immature, their aggression did not escalate to the dramatic levels seen in

the battles between unfamiliar adults, but it was much testier than that among typical siblings. Walsh has also demonstrated that the adolescents can distinguish their mother from an unfamiliar adult female by smell alone.

I am not entirely sure *why* the young amblypygids want to stay in close contact with other individuals, but they clearly do! If a clutch of young *D. diadema* are removed from a familiar cage and scattered inside a large, unfamiliar one, they gather back together within minutes. Do the amblypygids congregate into groups because certain areas of the cages—the tight spaces, such as where cork bark touches the glass walls of the cages—are more attractive than others? My student Lisa A. Taylor and I tested that hypothesis by putting family groups on more uniform “bark”—otherwise known as plywood—that we installed around the walls of the cage,

equidistant from the glass. When we observed where individuals distributed themselves, we were rather surprised that both species gathered together in small groups on the plywood, but that the location of the gatherings changed daily. Individuals were less interested in certain spots in the cage than in simply associating with others in their group.

Another common benefit of group living is that it affords some protection from predators. Group members can take turns as lookouts, warn their neighbors of impending danger, or help defend against incursions by outsiders. Amblypygids must



Upper photograph: Damon whip spiders are pictured in courtship. Lower photograph: Female *D. annulatipes* from South Africa, when turned on her back, exposes a brood pouch. Dozens of young will soon hatch and climb onto her back.

be preyed upon by other animals (and not only by the desperately greedy people on the television show *Fear Factor*), but surprisingly few reports have surfaced of the capture of amblypygids by other animals in the wild. Only a scorpion in Costa Rica and an Amazonian monkey, the golden backed uakari, have been observed eating amblypygids.

Response to the risk of predation is hard to test realistically in the laboratory. We found, however,



Freshly-molted male whip spider (*D. diadema*) leaves behind an old, dark exoskeleton. After a day, the animal's white exterior will darken and harden. Throughout their lives whip spiders molt in order to grow or rejuvenate.

that when we disturbed *D. diadema* families, the youngsters moved closer to their mother or siblings, or even scurried under their mother. As the young became adolescents, though, they were less likely to respond to a threat by gathering closer together. Most of the time, the adolescents as well as their mother just scuttled rapidly away from a threat. But every once in a while a mother threatened us. On several occasions an adult female with seven-month-old offspring tried to defend her young with an effective threat display. Each time she raised her body high above the bark, opened her palps widely, and slowly stalked toward us. The display made her look even larger and more threatening. Once she tried to stab me with the stiletto-sharp tip of her palps. Believe me, I backed off as fast as I could!

I mentioned earlier that group living often helps facilitate the capturing and sharing of large prey. Among spiders, pseudoscorpions, and scorpions, prey

sharing is one of the major benefits of social living. Immature animals, in particular, have the advantage of getting much larger prey than they could capture by themselves. I am a behavioral ecologist who believes that amblypygids should rightfully be considered part of the pantheon of social arthropods, but I can't defend my position by claiming that amblypygids share prey or cooperate in prey capture. On rare

occasions, we have seen siblings or mothers and their young briefly share prey, but the behavior has seemed incidental, rather than reflective of cooperation or even mutual tolerance. More commonly, hungry group members try to steal prey from one another—a rather comical effort, because the thief often returns to the center of the group to eat its ill-gotten gains, only to have the meal stolen once again.

Another important difference between amblypygids and most other social arachnids is that the amblypygids construct no communal retreat. They cannot produce silk, so webs are not an option. Nor do they dig burrows. But perhaps they have no need to collaborate on a retreat. Amblypygids are so thin they can fit into narrow spaces where they are safe from predators and from the elements. Groups of young siblings often pack into tight spaces, leaving only their whips waving at the entrance.

In fact, young amblypygids are remarkably hard to see. Even after years of observing them, I rarely locate the youngsters right away. Instead, I tend to glimpse first the white “elbows” on their whips, next the movement of the waving whips, and only then do I recognize that six or ten fingernail-size youngsters are right before my eyes. Their camouflage probably explains why social behavior in amblypygid families in the wild has not yet been explored. An adult female can be relatively easy to find when she is foraging alone at night, but her nearby offspring may be virtually invisible if the light is dim and the background is at all complex.

Yet as people look carefully for young amblypygids in the field, I predict biologists will discover more of these fascinating animals living in family groups. They may be peculiar looking—even off-putting to some—yet I cannot help but be charmed by their peaceful family dynamics where siblings entwine whips and explore their surroundings together. One must admit that in their mastery of social grace, they are incredibly alluring. □

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Ozark Mushrooms

Bedecked with resilient plants, an Arkansas cliff top overlooks fantastic formations known as pedestal rocks.

By Robert H. Mohlenbrock



The Ozark Mountains are centered in Missouri, but they extend into northwestern Arkansas, where they fall largely within the Ozark National Forest. The Arkansas Ozarks are a rugged region of high peaks, steep cliffs, ravines, and various unusual rock formations. Some of the most intriguing formations are part of a rocky escarpment along the upper reaches of the Illinois Bayou River drainage. Many, known as pedestal rocks, are shaped like giant mushrooms, with an enlarged top supported by a narrow shaft. Others are blocks pierced by “windows” or weathered into natural arches. You can enjoy all those forms—along with panoramic views—in the Pedestal Rocks Scenic Area of the forest’s Bayou Ranger District.

The Ozarks originated some 300 million years ago when the region uplifted to form a large dome, the Ozark Plateau. Since that time the elements have ceaselessly eroded the plateau. The oldest rocks, exposed near its center in eastern Missouri, include granite and volcanic rock. In Arkansas, however, the exposed rocks are younger, sedimentary layers of limestone, sandstone, and shale, originally deposited by rivers and shallow sea waters. At Pedestal Rocks, the exposed deposits are of sandstone. The unusual rock formations result when sections of sandstone begin to separate from the edge of the cliff and are shaped by the combined action of wind, water, and frost.

From a parking lot and picnic area

Carved by wind, rain, and frost, a pedestal rock rises twenty-five feet high.

Dry woods Oaks and hickories are the dominant trees; the most prevalent of their species are chestnut oak, northern red oak, red hickory, shagbark hickory, and white oak. Among the other major tree species are black cherry, black gum, black walnut, eastern witch hazel, flower-

ing dogwood, red maple, shortleaf pine, slippery elm, and white ash. Shrubs are relatively sparse. They include dwarf sumac, hop tree, shrubby Saint-John’s-wort, and smooth sumac. Woody vines, by contrast, are common, and include fox grape, poison ivy, four kinds of prickly green-

briers, summer grape, and Virginia creeper.

Among the nonwoody species are Indian physic, rough-leaved goldenrod, two skullcaps, spreading sunflower, Sullivant’s coneflower, five kinds of tick trefoils, white avens, white lettuce, and white-leaved mountain mint.

Rocky rim and exposed bluff The gnarled trees are black hickory, blackjack oak, eastern red cedar, post oak, scarlet oak, and winged elm. Shrubs include dwarf hackberry, farkleberry, and lowbush blueberry, all with leathery leaves. Wildflowers with very small leaves include

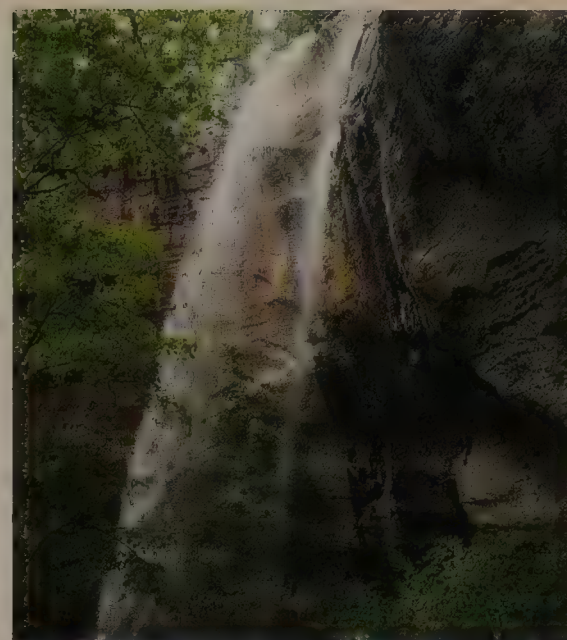
along Arkansas State Route 16, visitors can follow two trails into the scenic area. The Pedestal Rocks loop, a round trip of about two and a quarter miles to the rim of the escarpment, provides a view of the pedestal rocks, which stand below, off the edge of the cliff. Another, shorter loop goes to King's Bluff, a flat, rocky expanse, also along the rim of the escarpment, that after a rain becomes the top of a hundred-foot waterfall. Both trails pass through typical Ozark upland forest. The vegetation is diverse, despite the fairly dry and hot conditions that prevail in the summer.

All along the rim there are plenty of open stretches of what looks like bare rock, though on close inspection the surface often proves to be

covered with a thin layer of lichens. Interspersed among those bleak areas are microhabitats more hospitable to vegetation. Rainwater flowing to the rim in rivulets from the upland woods has carved narrow channels where soil has accumulated. Periodically replenished by rain, the channels usually remain wet and muddy throughout the summer, enabling several fern and wildflower species to grow as high as three feet.

Other plants survive in slight depressions where soil has accumulated. After a heavy rain, water stands in the depressions for a while, creating mini-wetlands, some just two or three feet across. Although the water may eventually be lost to evaporation or seepage, some of the species that grow here also occur in more substantial wetlands along streams and around ponds. Such cliff-top depressions are also the exclusive home for limestone quillwort, a spore-producing species related to the ferns. It's a plant you would have to search out between mid-March and mid-June, because after that, its leaves wither away. It is easy to pass by, in any case, because it looks like a small tuft of grass about six inches tall.

I must admit a special fascination for plants that can survive on rock surfaces that are practically bare and exposed to intense, direct sunlight. Depending on the kind of rock (as well as on regional terminology), such habitats may be known by such terms as barrens, glades, or pavements. In spite of the paucity of soil, several tree species have gained a tenuous foothold, often getting moisture



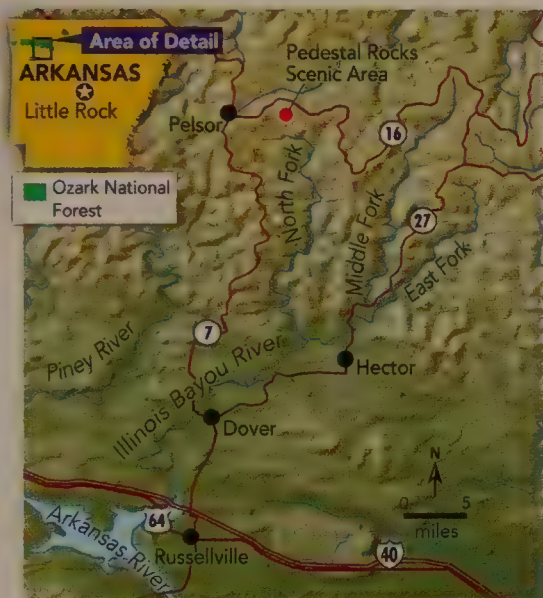
Cascade at King's Bluff, in early-spring flow

and anchorage by sending roots deep into fissures. Among them are black-jack oak and post oak, whose leathery leaves, covered by a thin coating of wax, reduce water loss. Because of the harsh conditions, however, such trees are usually small and gnarly.

Other plants have adapted with small or even threadlike leaves, which expose little surface to the sun's rays. Leaf surfaces may be covered with scales or hairs. Succulent leaves store water for later use in extremely dry conditions. In the prickly pear, a cactus, the leaves have evolved into spines, and water is stored instead in the fleshy stems.

Then there are the so-called spring ephemerals, plants that simply beat the heat and drought by germinating during March, flowering and going to seed during April and early May, and drying up by the end of May.

ROBERT H. MOHLENBROCK is distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.



VISITOR INFORMATION

Bayou Ranger District
Ozark-St. Francis National Forest
12000 State Route 27
Hector, AR 72843
470-284-3150
www.fs.fed.us/oonf/ozark/recreation/pedestal_rocks.html

nits-and-lice, pinweed, and pinweed. Thread-leaved sundrops, a kind of evening primrose, has, well, thread-like leaves. The leaves of a few plants, such as rushfoil, have a scaly surface, whereas those of goat's-rue are hairy. Prickly pear stores water in its fleshy stems; plants with

succulent leaves include fame flower, Illinois agave, and widow's-cross.

Spring ephemerals include three kinds of bluet, a delicate grass known as six-weeks fescue, and yellow star grass. Hairy lip fern and rock spikemoss are tiny spore-producing plants that simply

dry out and curl up during drought, but a summer rain is all it takes to revive them.

Small depressions in the rock surface Dwarf Saint-John's-wort, rough buttonweed, three small sedges, and small-flowered bittercress are among the wetland plants.

Limestone quillwort also grows here.

Blufftop channels Christmas fern, Ohio spiderwort, polypody fern, slender mountain mint, toad rush, winged crown-beard, and woodland oatgrass are among the species that grow in the moist soil.

George Tooker, *Sleepers II*, 1959

*The Family That Couldn't Sleep:
A Medical Mystery*
by D.T. Max
Random House; \$25.95

Among the manifold ways we may depart this mortal coil, none are more terrifying than those that involve the slow disintegration of the central nervous system. So first, a warning: do not read this book—or even this review—unless you are absolutely immune to suggestion and hypochondria. Otherwise, journalist D.T. Max may scare you sleepless with tales of innocent people whose bizarre symptoms slowly turn horrific.

Do you perspire profusely and have trouble getting a good night's sleep? Have your pupils shrunk to the size of the dot over this "i"? Those are signs of fatal familial insomnia (FFI), a hereditary malady so rare that it afflicts only forty families worldwide. Do you stumble from time to time? Do your arms cross uncontrollably whenever you turn your head? Those difficulties may signal Gerstmann-Sträussler-Scheinker disease, first recognized in a twenty-six-year-old Viennese woman in 1928, and now diagnosed in one in a hundred million people worldwide. Do you smack your lips reflexively when you are tickled under the chin? Sheep do,

when they contract a degenerative brain disease called scrapie. No cases of sheep-to-human transmission are known, but after eating contaminated beef, more than 150 people have died of the bovine variant of scrapie, bovine spongiform encephalopathy, or "mad cow disease," a degenerative brain disorder called in humans "variant Creutzfeldt-Jakob disease."

What all those maladies have in common is that they are caused by prions, abnormal forms of small proteins that quite normally occur in animal and human cells. Prions do not reproduce like bacteria or viruses, but under certain conditions they can propagate uncontrollably, the way a slight crack in a windshield can turn into a web of fissures across the entire pane.

Since the outbreak of mad-cow disease in Britain in the 1980s, and the consequent destruction of millions of cattle, prion diseases have generated almost as much public fear as urban terrorism. Prions seem impervious to antibiotics; they survive boiling, ultraviolet radiation, and soaking in formaldehyde. They can remain dormant in the body for years, making it possible for prion infections to become epidemic long before symptoms are apparent. And they are invariably fatal. The only upside of prion diseases, if

you can call it that, is that they are hard to catch and extremely rare.

Max is the latest of many excellent writers who have reported on prions, but his book is probably the most gripping and sympathetic. He himself suffers from a rare neuromuscular (nonprion) disease. Throughout his story of prions, he threads the saga of an Italian family plagued by FFI, perhaps the most gruesome prion disorder of them all: it leaves cognition intact while the victim, unable to eat or sleep, twitches uncontrollably until the end. Doctors have only recently identified the cause of the debility, which has carried away generations of uncles, cousins, and parents. One hopes that, before another generation has passed, science will find a cure, not just a reason, for their affliction.

*Richter's Scale:
Measure of an Earthquake,
Measure of a Man*
by Susan Elizabeth Hough
Princeton University Press; \$27.95

For more than forty years, from 1927 until his formal retirement in 1970, Charlie Richter was an employee of the Seismological Laboratory, long a part of Caltech, in Pasadena, not far from his childhood home in Los Angeles. His work, for the most part, was routine: compiling and analyzing records from a network of earthquake detectors scattered around the area. Off-hours, he lived in a modest house with his wife and a few pets, enjoyed music, and belonged to a local book group. When time permitted, he would hike alone in the mountains. But apart from that, he shunned travel, seldom venturing out of the country—or out of the state, for that matter. Not the kind of life, one would imagine, to merit a 300-page biography.

Yet Charles Francis Richter was, and is, perhaps the most famous seismologist of our time, a man whose name is mentioned in news reports

every time a large quake hits. The first thing an inquiring public wants to know is: How strong? The expected answer is one measured by Richter's scale of magnitudes, even though its scientific usefulness has largely been superseded by more modern standards.

The real Charles Richter, fellow seismologist Susan Hough would have us understand, was neither drudge nor genius, but a complex and gifted man who made fundamental contributions to his field. She is also at pains to recount her subject's highly unconventional personal life. Hough bases her profile on public documents; interviews with surviving family, colleagues, and acquaintances; and most of all, a wealth of personal papers. Richter, you see, left seemingly everything he ever wrote to the Caltech archives—perhaps in anticipation that one day a biographer would tackle the task of putting his life in order.

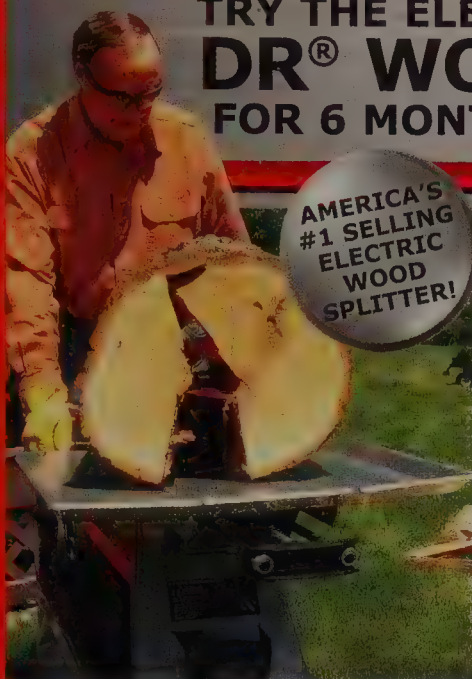


Charles Richter, circa 1952

No one can quibble with Hough's assessment that the intensely private seismologist was a most unusual man. In appearance, he was the quintessential nerd—bespectacled, baby-face smile, and hair flying in all directions. True to stereotype, he kept detailed records of all the *Star Trek* episodes he watched. But Richter was much stranger than stereotype. For

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most of their lives he and his wife were active nudists, sunning themselves at various “naturist” camps around the Golden State. He was the author of several unpublished novels, as well as painfully self-referential poetry, some of it published—reams of verse, from which, thankfully, Hough quotes with restraint. Judging from some of his poems and letters, he may have carried on several extramarital affairs.

As a scientist, though, Richter earns Hough’s admiration. According to his colleagues, he was a veritable encyclopedia of information about earthquakes, and a tireless advocate for improving building designs in quake-prone areas.

But Hough has a harder time coming to terms with Richter’s quirky personality. She strongly suggests that Richter suffered from Asperger’s syndrome, a mild form of autism, which could account for both his ability to concentrate on details and his difficulty in connecting with people. Of course, it’s always dangerous to

psychoanalyze from a distance. But the famous earthquake expert, she surmises, was a man equipped “with a three-hundred-horsepower engine and a transmission that slipped madly between gears,” who followed his own peculiar highway through life’s unsteady terrain.

*Human Anatomy: From the
Renaissance to the Digital Age*

by Benjamin A. Rifkin
and Michael J. Ackerman,
with biographies by Judith Folkenberg
Abrams, New York; \$29.95

In medicine, as in many other professions, the distinction between science and art is a contemporary idea, dating to no earlier than the 1800s. That observation is particularly relevant to the history of anatomy, the focus of this magnificent collection of classic reproductions from the holdings of the National Library of Medicine in Bethesda, Maryland, and the

Thomas Fisher Rare Book Library at the University of Toronto. Furthermore, the images have been annotated by a team of modern-day specialists: an art historian (Rifkin), a biomedical engineer and pioneer in bioinformatics (Ackerman), and a writer/book artist (Folkenberg).

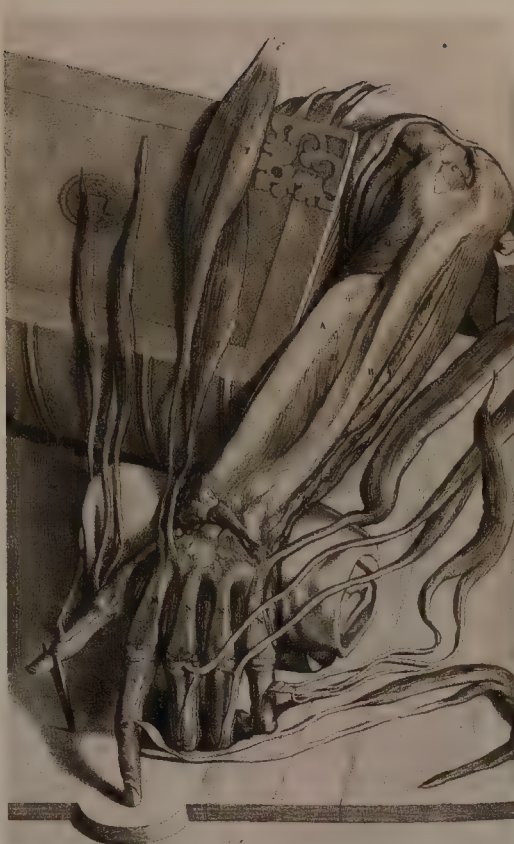
Contrast the pictures on display here with the ones in any surgical manual of recent vintage, depicting exposed or disembodied organs and tissues against a featureless background. In the florid engravings of earlier centuries, the central figures often appear as elements of larger naturalistic or formal compositions. In Andreas Vesalius’s landmark text on the human body, *De humani corporis fabrica libri septem*, published in 1543, a skinned cadaver vogues against the background of an Italian village; a skeleton in Charles Estienne’s 1545 dissection manual stands contemplatively before a bucolic lake, holding out its detached mandible for inspection; a disembodied arm in Govard Bidloo’s 1690 album of anatomy rests



on a table as matter-of-factly as a bowl of fruit in a still life.

To modern eyes, those settings seem distracting. And at times they are unsettling, particularly when the bellies of pregnant women are drawn as if cut open, to show the form and position of the fetus, or when mouths are incised and spread to illustrate the structure of the lips, tongue, and teeth. The most bizarre, hands down, are engravings from the *Thesaurus anatomicus primus* (1701–1716) of Frederik Ruysch, an anatomy professor from Amsterdam. They are a partial catalog of his personal cabinet of curiosities, a collection of preserved body parts, bones, and fetuses that represented not only abnormalities and rarities of the natural world, but also the grotesque imagination of Ruysch himself. Some of them show tableaus created with fetal skeletons, posed amidst surrealistic landscapes constructed of stuffed birds, bovine tracheas, and kidney stones.

In spite of their conflation of art and science, early anatomy texts re-



Engraving artfully drapes the muscles and tendons of a forearm and hand (from the 1690 edition of *Ontleding des menschelyken lichaams* [Anatomy of the Human Body], by Govard Bidloo).

quired the collaboration of specialists: master surgeons whose skill with scalpel and dye highlighted organs of interest; artists who could sketch faster than cadavers decay; and engravers who could render not just form, but texture and contrast.

In the twenty-first century, online databases such as the Visible Human Project (www.nlm.nih.gov/research/visible) make it possible to view anatomy from any angle, distance, or functional perspective with a precision the earlier masters could not hope to achieve. CAT scans and MRIs can render the particular internal structure of any individual on demand. Still, the pioneering works showcased here stand as elegant testimonials to how far science has come, and how long art endures.

LAURENCE A. MARSCHALL, author of *The Supernova Story*, is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.

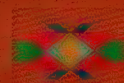
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Not Seeing Is Believing

The existence of dark matter is confirmed—again.

By Charles Liu

Dark matter is everywhere. According to current theory, it permeates our solar neighborhood, surrounds our Milky Way, and envelops every other substantial collection of matter in the universe. It's so dilute that astronomers can't even detect its presence in our solar system, yet on scales of millions of light-years, it's the dominant source of gravity in the cosmos. What's more, it's not made up of the same stuff we're made of—electrons, neutrons, and protons. And, true to its name, it's dark: Not only does it give off no visible light, but it's also dark across the entire electromagnetic spectrum. No gamma rays, no X-rays, no waves of ultraviolet, infrared, microwave, or radio frequency issue forth from dark matter anywhere.

So what is dark matter?

Astrophysicists still don't know, but its existence has been tested again and again in the past few decades, and has been confirmed in various ways by a number of investigators. Yet despite all the tests and confirmations, plenty of people remain skeptical. Could another explanation be consistent with the observations?

The question, of course, is specific to astrophysics, but that *kind* of question would be familiar to investigators in virtually any scientific discipline. Whenever an accepted



Aftermath of the collision of two galaxy clusters is shown in this composite of X-ray, optical, and gravitational-lensing images of the object 1E 0657–56. The two colliding galaxy clusters (each white or orange speck in the two purple patches is a galaxy) have passed through each other; hot gas (pink) that was once part of each cluster was slowed by the collision and now lags behind its former cluster. The purple overlay indicates higher distortion by gravitational lensing, hence greater mass. It shows that mass is concentrated in the two galaxy clusters, even though the hot gas far outweighs the galaxies' combined luminous mass, confirming that each cluster is permeated and surrounded by a huge amount of unseen, cosmological dark matter.

scientific theory can't explain a set of observations, scientists have three options: discard the theory and propose a new one; expand the theory to account for the anomalous data; or propose an alternate explanation for the observations that shows how the theory remains sound. That, by the way, raises a fundamental difference between science and nonscience: no scientific knowledge is so sacred that it can't be tested, challenged, and ultimately superseded.

Here's another fundamental dif-

ference between science and non-science. No matter which of the three options they choose, scientists must push the new or revised ideas to their logical conclusions, deriving new predictions from them and testing the predictions repeatedly with new experiments and observations. A proposed but untested explanation is not a scientific explanation at all. It remains hypothetical—maybe an educated guess, possibly even a correct guess, but a guess nonetheless.

So it is with the theory of dark matter. A few scientists have supported an alternate explanation for the observations that dark matter is supposed to explain. Their idea is that Newton's second law of motion needs to be subtly modified. If its correctness could be confirmed, many observations that seem to point to dark matter could be explained in terms of ordinary matter alone.

Mind you, these "modified force" guys are part of only a small dissenting minority on the dark-matter issue. Yet dismissing their ideas would hardly be scientific, either. The scientifically right thing to do is to conduct experiments or make observations that clearly distinguish between a modified-force law

and a preponderance of dark matter. Recently, a team at the University of Arizona led by Douglas Clowe, now of Ohio University in Athens, made just such an observation.

How much testing must be done before a hypothesis becomes established scientific knowledge, or else is discarded? It depends. If an idea is revolutionary, it must be confirmed often and in many independent ways before it is accepted. A classic example is the history of the theory of gravity. In the seventeenth century, Newton's

theory explained the orbits of the planets around the Sun. The theory was revolutionary, but it was repeatedly confirmed.

But Newton's theory of gravity was eventually supplanted by an upgrade, as it were. Einstein's theory of gravity—general relativity—added the critical idea that space-time curves. General relativity, however, was nothing more than an elegant hypothesis until 1919, when observations of the apparent positions of stars during a solar eclipse confirmed one of its major predictions—that matter can bend space-time.

Less than two decades later, general relativity appeared subject to its own apparent anomalies. In the 1930s the American astronomer Fritz Zwicky measured the speeds of galaxies in a cluster in the direction of the constellation Coma Berenices as they orbited their common center of gravity. To his great surprise, he found that the typical speed of the orbiting galaxies was about 2 million miles an hour! At those speeds, so many galaxies would have escaped the cluster's collective gravitational pull so quickly that the cluster could never have formed in the first place. And yet, there it was, hale and hearty—in direct observational contradiction to Einstein's established theory of gravity.

Like all good scientists, Zwicky had to choose: new theory, revised theory, or same theory with alternate explanation? Zwicky chose door number three—and came to an astounding conclusion: a vast amount of invisible, or “dark,” matter must be lurking in the Coma cluster, far outweighing the combined mass of the galaxies in the cluster. Only such dark matter could provide the gravitational “glue” necessary to hold the cluster together.

The recent work of Clowe and his collaborators centers on an object far more distant and complex than the target of Zwicky's studies. Designated 1E 0657-56, the object, about 3 billion light-years from

Earth, is actually a merger of two galaxy clusters that looks like a gargantuan, asymmetric dumbbell [see image on opposite page]. Each cluster, or “knob” of the dumbbell, is actually made up of hundreds of galaxies, and the two clusters are more than 2 million light-years apart. (By comparison, our entire solar system, out to the orbit of Pluto, is about 0.001 light-year across.)

The clusters appear to have passed through each other after a head-on collision that began some 100 million years ago. Traveling like two schools of cosmic fish, the galaxies in the clusters flew right by one another at millions of miles an hour. But the diffuse, ionized gas that permeated the space between the galaxies didn't pass through quite as cleanly. Instead, the gas clouds dragged behind, billowing like two giant jellyfish in the space between the clusters. All that gas is more than twice as massive as the star-laden galaxies, based on estimates of its density and its volume from X-ray images. The result is that even though the galaxies are concentrated in the clusters at either end, the ordinary matter is concentrated near the center of the dumbbell, in the form of lingering ionized gas. So if there were no dark matter in the dumbbell, its gravity should be strongest in its central region and weaker at each end.

Clowe and his colleagues were able to measure how gravity varies across the entire dumbbell by charting how it acts as a gravitational lens: how the images of distant galaxies behind 1E 0657-56 are bent or distorted because of the space-time curvature in its vicinity—as the light passes through its various parts. The resulting gravitational-lensing map showed clearly that most of the mass of 1E 0657-56 is concentrated around the galaxy clusters—not in the center, where the gas remains, even though the hot gas far outweighs the combined stellar mass of the two clusters.

A modified-force law simply can't explain that observation. Something



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A Trip to Australia Reveals the Wonder of Giant Golden Pearls

Just before 1900, in a small isolated town called Broome Australia, fishermen came across the rarest oyster—a giant named the *Pinctada maxima*. This world's largest oyster contained the voluptuous South Sea Pearl—the most sought after pearl in the world. After this discovery, Broome soon became the dominant pearl trading post in the world and literally 80% of all worldwide pearl trading passed through Broome.

A trip to Broome. We took the long trip to Australia to study the famous white lipped oysters that produced magnificent pearls that are often 11-14mm—about 8 times the size (and 8 times the price!) of a standard pearl. Not only did these oysters produce the rare South Sea pearl, but they also produced a tremendous amounts of mother of pearl or nacre. Nacre is the lustrous iridescent substance which is secreted by the oyster to form the shiny inside of their shells. When nacre secretions are deposited around the pearl seed they build up to form a full sized pearl. Our bio-scientists went to work to see if we could improve upon Mother Nature's process a little. By extracting the seed pearl from young oyster shells and speeding up the process in the lab, we coated these natural seed pearls with nacre from the inside of the giant shells, and were able to produce the breathtaking hand-coated Australian Pacific Pearl.

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have to worry about perfumes or cosmetics discoloring these pearls like you do with ordinary pearls. In a more ecologically friendly approach, the Australian Pacific pearl seed is extracted from fresh oyster shells and then organically micro-coated in the laboratory with the same nacre that coats naturally grown pearls. Giant 12mm golden South Sea pearls can cost up to \$50,000 for an 18" strand. Why even think about that when you can now wear an 18" strand of 12mm hand-coated enhanced Australian Pacific Pearls with a consistently round shape and a rare golden color for under \$300.

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around and within the two clusters of galaxies, other than ordinary matter, is generating most of the gravitational pull in the system.

What could this something be? Lots and lots of dark matter remains the best answer.

So once again, and in a new and unambiguous way, the reality of dark matter has been confirmed. Has that finally put the controversy to rest? Can we astronomers at last take its existence as truth?

Um, no and yes. No, because both as a scientific community and as individual scientists, we should never reject the possibility—however remote—that we are wrong. Yes, because with so many lines of overwhelming evidence in its favor, it would be silly to pretend otherwise.

Yet we'll also keep on testing our theories of dark matter at our laboratories and observatories. That's a good thing; it's precisely the kind of skepticism that elevates real scientific theory above the realm of mere hypothesis. And it's also the only way, after all, that we're ever going to get to the bottom of the great mystery of what dark matter really is.

CHARLES LIU is a professor of astrophysics at the City University of New York and an associate with the American Museum of Natural History.

PICTURE CREDITS Cover: Illustration by Viktor Deak; pp.6-7: Matthew T. Russell/www.telescopes.cc; p.8(bottom): Viktor Deak; p.9: Dolly Setton; p.13(top): ©ISM/Phototake, (bottom) Dave Verbyla; p.14 (left): ©The Natural History Museum London; pp.14-15: (top) Roger Hanlon, (bottom) ©Michael & Patricia Fogden/Minden Pictures; p.15: (middle) L.M. Mathger, (right) T.Torsvik & H. Furnes; pp.16-17: Christos Magganis; pp.22-29: Reconstructions ©G.J. Sawyer & Viktor Deak; Photographs ©Viktor Deak; Reproduced by permission of Nevaumont Publishing Company; pp.30-31: Veronica von Allworden; p.32: ©Hans Leijnse/Foto Natura/Minden Pictures; p.33: Patricia J. Wynne; pp.34-35: ©Fred Bavendam/Minden Pictures; p.36: Courtesy of the author; pp.38-39: ©Piotr Naskrecki/Minden Pictures; p.40: ©Piotr Naskrecki; pp.41, 42 & 44: Linda S. Rayor; p.43: Peter Weygoldt; pp. 46 & 47: Ronnie C. Rackley; p. 47: Map by Joe LeMonnier; p.48: Digital Image ©The Museum of Modern Art/Licensed by SCALA/Art Resource, NY/Courtesy DC Moore Gallery, New York; p.49: Courtesy of the Archives, California Institute of Technology; p.51: Human Anatomy (Abrams), National Library of Medicine, Bethesda, Maryland; p. 52: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.; p.64:(top) Heiti Paves, (left) Jeffrey R. Holt and Jessica R. Risner, (middle) Spike Walker, (right) Tora Bardal, (bottom) Dylan Burnette

February begins with **Mercury** in prime position for evening viewing. When darkness falls on the 1st, the innermost planet glows low in the west-southwest at magnitude -0.9 and sets about eighty minutes after the Sun. From the 1st through the 11th, Mercury will be within ten degrees and to the lower right of brilliant Venus (your clinched fist held at arm's length measures roughly ten degrees against the sky). The two planets appear closest together, approaching within slightly more than six degrees of each other, on the evenings of the 4th and 5th. Then they quickly draw apart.

On the 7th Mercury reaches its greatest eastward elongation, or apparent distance from the Sun, moving eighteen degrees east of the Sun. That delays the planet from setting until evening twilight comes to an end. As Mercury descends in the western sky, it lies almost directly above the part of the horizon where the Sun had set earlier. For observers at forty degrees north latitude, Mercury is also near its maximum altitude, eight degrees above the horizon at midtwilight (forty-five minutes after sunset)—the second-highest evening altitude the planet attains in 2007. The planet fades quickly thereafter by a factor of almost five in brightness, from magnitude -0.2 on the 9th to $+1.5$ by the 15th. Thereafter it becomes lost from view on its way to inferior conjunction with the Sun on the 23rd. Through a telescope, Mercury appears at midmonth as a rapidly thinning crescent.

Venus is likely to be the first “star” you see through the twilight after sunset; look for it in the west-southwest. With each passing week Venus moves higher and grows brighter. But it still isn't much to look at in a telescope, appearing as just a tiny, slightly gibbous ball. Observers can see nearly all of its illuminated face because it is now on the far side of the Sun as viewed from the Earth. On the evening of the 19th a slender crescent Moon, about two

and a half days past new, rides well above Venus.

Mars rises just after dawn throughout the winter and much of the spring. Although it shines at magnitude $+1.3$, the Red Planet's low altitude in a brightening sky makes it a challenge to see, even for observers with binoculars.

Jupiter rises well after midnight and shines brightly in the southeast to south-southeast in the dawn twilight. At daybreak—an excellent time for observing Jupiter telescopically—the planet is higher in the sky than it has been since late last summer. The noble planet shines at about magnitude -2 , as it creeps eastward through the feet of the constellation Ophiuchus, the serpent holder, and away from the bright star Antares, situated below and to the right of the planet.

Saturn reaches opposition to the Sun

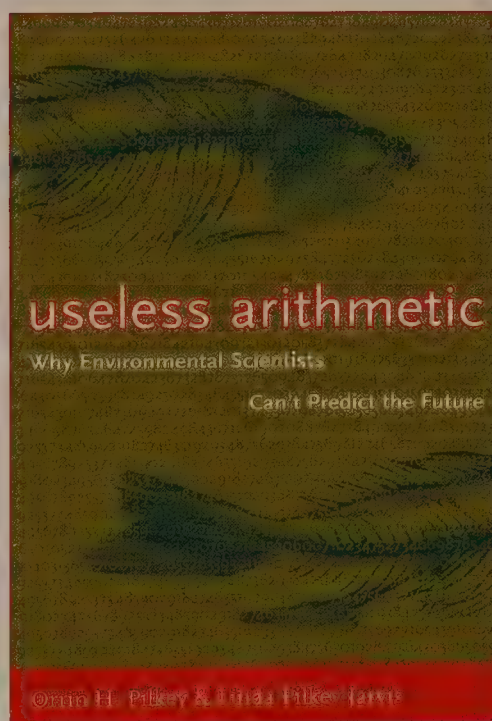
on the 10th. Thus it is visible all night long, shining as a bright (zero-magnitude), yellowish-white interloper in the constellation Leo, the lion, just to the west of the easily recognizable “sickle” of stars. It is now at its brightest and (for observers with a telescope) biggest. The rings, which have been tilting increasingly edge-on since 2003, are still inclined at about a fourteen-degree angle toward Earth, making for a grand sight even in a small telescope. Take note of Saturn's position relative to the full Moon on the evening of the 2nd; the Ringed Planet is the bright “star” above and to our satellite's right.

The **Moon** is full on the 2nd at 12:45 A.M. It wanes to last quarter on the 10th at 4:51 A.M., and to new on the 17th at 11:14 A.M. The Moon waxes to first quarter on the 24th at 2:56 A.M.

Unless otherwise noted, all times are eastern standard time.

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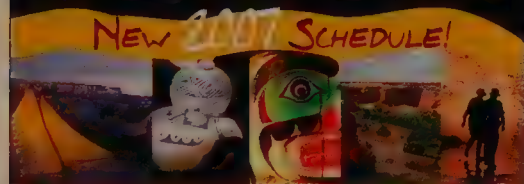
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Of Arms and the Brain

By Robert Anderson

Last summer my son and I went snorkeling in the chilly waters off Catalina Island, along the California coast. As we swam above a kelp forest swaying with the surf, we spotted fish by the hundreds. Then my son pointed excitedly toward a yellowish-brown creature jetting along the rocky bottom. Sliding over some dark green stones, it instantly changed to a matching color, vanishing from sight as if by magic. This master of camouflage, I later learned, was a California two-spot octopus.

Members of the Cephalopoda, the class that includes cuttlefishes, nautilus, and squids, along with octopuses, can change appearance in seconds. You can watch marine biologist Roger T. Hanlon's clip of the action by going to video.google.com and typing in "chameleon octopus" to access the video. To see a species that does more than just disappear into the background, type "Indonesian mimic octopus." That takes you to a short video of an octopus that mimics any one of three toxic species that occur in its native waters: a lionfish, a sea snake, or a sole.

"The Cephalopod Page" (www.thecephalopodpage.org), maintained by James B. Wood, a research scientist at the Bermuda Institute of Ocean Sciences in St. George's, is a good place to discover what features besides camouflage make cephalopods so fascinating. Near the top of the page, click on the "Lessons" section to select among the modules on cephalopod biology. There you'll find out about the mechanics of quick color changes and the physiology of the cephalopod eye, which is similar to our own. Or click "Cephalopod Articles" on the menu at the top to find more detailed (and marvelous) information: for example, "20,000 Tentacles Under the Sea: Cephalopods

in Cinema," by the marine biologist Roland C. Anderson of the Seattle Aquarium, examines the creatures' horror-movie appeal and lists their film credits.

Their fearsome reputation is not entirely unfounded. Recently Japanese investigators, filming nearly 3,000 feet, caught on camera an adult giant squid, with an arm span (tip to tip) of twenty-six feet, in the act of hunting—the first images of an adult both alive and in the deep (go to news.bbc.co.uk/1/hi/sci/tech/4288772.stm and click on the video near the upper right).

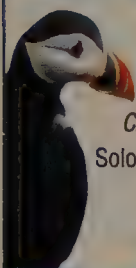
Still, their monster image notwithstanding, cephalopods are an important source of the world's protein, as well as a favorite animal in medical research. At the Web page of the National Resource Center for Cephalopods at the University of Texas Medical Branch (www.utmb.edu/nrcc), click on "Cephalopod Literature and Information Resources" and then on "The Peerless Squid" for an overview of how the study of the squid's giant nerve cell, with its readily manipulated pencil-lead-thick axon, has led to key discoveries in neuroscience.

Of all the invertebrates, the giant Pacific octopus is often cited as the most intelligent. David Scheel, a marine biologist at Alaska Pacific University in Anchorage, has a site devoted to the animals (marine.alaskapacific.edu/octopus), which notes that they can reach several hundred pounds and span nearly two dozen feet from arm tip to arm tip. PBS's *Nature* series has the most startling video clip of all—an excerpt from "The Octopus Show" (www.pbs.org/wnet/nature/octopus). The keepers at the Seattle Aquarium kept finding the remains of four-foot-long sharks in their tank for big fish. Nighttime filming caught the culprit red-armed: the giant Pacific octopus they had innocently placed in the enclosure was snacking on the so-called "top" predator.

ROBERT ANDERSON is a freelance science writer living in Los Angeles.

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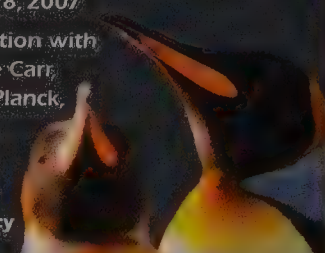
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AMNH to Confer Doctoral Degrees

For nearly a century, graduate students have conducted doctoral research at the American Museum of Natural History, but always for a degree at another institution. Until now. The American Museum of Natural History is now the first—and only—American museum to grant its own Ph.D. degree. Under authorization by the New York State Board of Regents, candidates for a doctorate in comparative biology will study and work within the Museum's unparalleled collections and laboratories in the newly established Richard Gilder Graduate School, with its faculty drawn from an internationally recognized staff of curators.

"The Gilder Graduate School, capitalizing on the Museum's unique and unrivaled combination of scientific leadership, world-renowned collections, and active program of field research, will train the next generation of scientists to investigate many of the most pressing issues confronting society in the 21st century," said AMNH President Ellen V. Futter.

The new Ph.D. candidates will work in some of the most advanced scientific facilities in the world. Located within the



D. FINNIN AND C. CHESK/AMNH

Graduate students pursuing advanced degrees in comparative biology at the Museum will have plenty of paleontology and other specimens at their fingertips in the treasured public galleries as well as in the Museum's collection of more than 30 million specimens.

Museum are three molecular laboratories, a powerful parallel computing facility, a frozen tissue collection with a capacity of one million samples, an imaging and microscopy laboratory, more than 30 million specimens and cultural artifacts, and the largest independent natural history library in the Western Hemisphere.

The American Museum of Natural History has long been known for its comprehensive approach to biological studies. Michael J. Novacek, Provost, Senior Vice President, and Curator in the Museum's Division of Paleontology predicted, "Profound biological discoveries will come from examination of myriad species. Here, we link emerging information on genes, form, and species diversity in a way that powerfully informs our understanding of the evolution of life."

The first class of the Gilder Graduate School, a select group of 8 to 10 students, is scheduled to arrive in September 2008.

Four donors have, combined, given more than \$50 million to support the new graduate school in endowment, fellowship support, and capital enhancements required to accommodate the new Graduate School: the Gilder Foundation, the Hess Foundation, Inc., an anonymous Museum Trustee, and the City of New York—the Department of Cultural Affairs and the New York City Council.

PODCAST NEWS

The next time you assume that teenagers with the tell-tale wires hanging down from their ears are zoning out to the latest band on their iPods, think again. They might just be pondering the legacy of Charles Darwin's voyage on the *Beagle* or learning the secret sticking power of a gecko's toes.

That's because the American Museum of Natural History, in collaboration with Science & the City, the online newsletter of the New York Academy of Sciences, is now posting its world-class educational content in free podcasts.

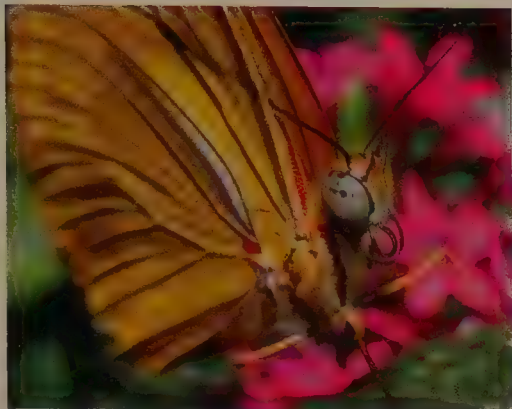
Podcasting, downloading audio files to a portable player or personal computer, expands the Museum's reach by providing access to lectures,

panel discussions, and other educational programs.

Just visit www.amnh.org/podcast, where you will find a list of podcasts by noted scientists and authors on everything from the 1906 San Francisco earthquake to biodiversity in New York City, the thrill of whale watching to what motivates someone to spend their life studying snakes.

I SPY A BUTTERFLY!

WWW.AMNH.ORG



H. DAVES/AMNH

Julia butterfly (*Dryas iulia*)

Unleash your inner lepidopterist with the Museum's online Butterfly Cam, which is focused on the colorful creatures of the in-house hothouse that is *The Butterfly Conservatory*, on view through May 28, 2007.

To get there, simply click on the exhibition itself at the Museum's home page, www.amnh.org, and follow the prompts to the Butterfly Cams.

As a bonus, you will also find three prerecorded film clips of monarchs and swallowtails enjoying a meal and the amazing spectacle of a zebra longwing emerging from its chrysalis.

Dedicated to Dunham

You dance because you have to.

—Katherine Dunham (1909–2006)

Katherine Dunham sought, in the native dances of the Caribbean, in the pounding rhythms of Africa, the cultural origins for the distinctive form of dance she pioneered. She spent her long life creating art of transcendent power and beauty, coupled with awareness of both racial inequality and ethnic pride.



PHOTOGRAPH BY CARL VAN VECCHTEN, MUSEUM OF THE CITY OF NEW YORK

Katherine Dunham in *Cabin in the Sky*, 1940

5:00 p.m., dancers and educators who studied with Dunham and the young stars who are influenced by her extraordinary work will perform, present panels, and screen films about Dunham and her remarkable life.

"I used to want the words 'She tried' on my tombstone," Dunham once said. "Now I want 'She did it.'" Dedicated to Dunham shows that, indeed, she did.

Dedicated to Dunham is coproduced by the American Museum of Natural History; Barbara Horowitz, founder and president of Community Works; and Voza Rivers, executive producer of New Heritage Theatre Group. Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, the New York City Council, and the New York City Department of Cultural Affairs. Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

PEOPLE AT THE AMNH

Leslie Martinez

Coordinator, Sleepover Program



D. FINNIN/AMNH

Every Thursday, when many people race for the door at the end of their workday, Leslie Martinez heads to the Akeley Hall of African Mammals for an evening animal drawing class. "I love it," she says. "It's a way to get to know the dioramas—and the Museum at night."

The Museum at night is Leslie's bailiwick now, as coordinator of the recently revived sleepover program in which 300 8- to 12-year-olds and adult chaperones explore the Museum after hours before setting up camp in the Milstein Hall of Ocean Life. "I only slept for one hour but it was all worth it," she emailed a colleague, exhausted but exhilarated after the first trial run in October. "It was amazing to see children with their favorite stuffed animals getting ready to sleep under the blue whale with their families."

Like so many AMNH employees, Leslie's enthusiasm is heightened by that of her daughter, Whitney, 10. "Whitney grew up here," says Leslie, who started at the Museum in 2001 as a part-time membership assistant while earning her B.A. in history at Baruch College. Whitney is also her best programming adviser. "She tells me what flies, what doesn't."

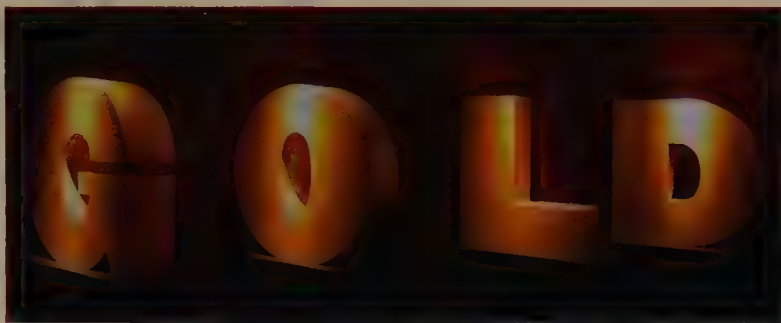
If there is a downside to her new job, it's turning someone away; for example, "a dinosaur-crazy 5-year-old on his birthday." But if Leslie has her way and the program keeps selling out as it has been, when that little boy turns 8, the sleepovers will still be going strong.

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY



www.amnh.org



R. MICKENS/AMNH

EXHIBITIONS

Gold

Through August 19, 2007

This glittering exhibition explores the captivating story of the world's most desired metal. Extraordinary geological specimens, cultural objects, and interactive exhibits illuminate gold's timeless allure.

Gold is organized by the American Museum of Natural History, New York (www.amnh.org), in cooperation with The Houston Museum of Natural Science. This exhibition is proudly supported by The Tiffany & Co. Foundation, with additional support from American Express® Gold Card.

The Butterfly Conservatory

Through May 28, 2007

Visitors mingle with live, free-flying butterflies in a tropical environment.

Yellowstone to Yukon

Through February 18, 2007

Spectacular photographs emphasize the diverse flora, fauna, and geology of the Yellowstone to Yukon wildlife corridor.

This exhibition was developed by the American Museum of Natural History's Center for Biodiversity and Conservation in concert with the Yellowstone to Yukon Conservation Initiative and the Wilburforce Foundation and is made possible by their support. Additional generous support provided by the Woodcock Foundation.

GLOBAL WEEKENDS

African-American Heritage Month: Dedicated to Dunham

Sunday, 2/25, 1:00–5:00 p.m.

A day of performances, workshops, and symposia celebrate

the life and legacy of anthropologist, dancer, choreographer, and teacher Katherine Dunham. See p. 61.



DAN DEITCH

LECTURE

Death by Black Hole: And Other Cosmic Quandaries

Tuesday, 2/13, 7:00 p.m.

Neil deGrasse Tyson introduces readers to the physics of black holes by explaining just what would happen to your body if you fell into one. He explores these "and other cosmic quandaries" in this entertaining and informative talk.

ADULT WORKSHOP

Bead Workshop

by Samuel Thomas

Sunday, 2/18, 12:00 noon–3:00 p.m.

Both East African bead winding and a similar technique used by the Iroquois will be demonstrated in this workshop with Iroquois beading artist Samuel Thomas and Munuve Mutisya,

founder and director of the Akamba Peace Museum in Kyanzasu, Kenya.

FAMILY AND CHILDREN'S PROGRAMS

Bones, Brains, and DNA

Saturday, 2/10, 2:00 p.m.

Rob DeSalle and Ian Tattersall have coauthored an engaging illustrated book, *Bones, Brains, and DNA*. DeSalle will examine both paleontological and genetic evidence relevant to human evolution with the help of Museum mice Wallace and Darwin, narrators of the book.

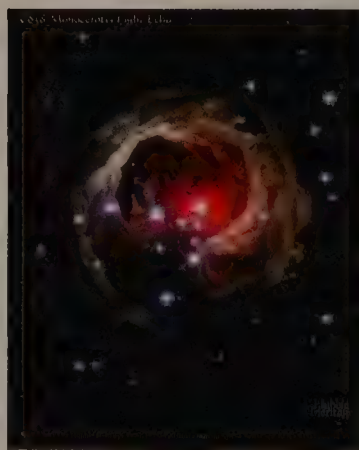
ASTRONOMY PROGRAMS

NEW! Twinkling Stars

Two Tuesdays, 2/6 and 13,

4:00–5:30 p.m. (Ages 4–6, each child with one adult)

Classroom activities and observations in the Hayden Planetarium Space Theater reveal the stars above and the ancient stories and traditions that have followed them through the ages.



NASA AND THE HUBBLE HERITAGE TEAM (AURA/STSC)

"Light echo" illuminates dust around a supergiant star.

NEW! Frosty Adventures

Sunday, 2/4, 11:00 a.m.–

12:30 p.m. (Ages 4–5, each child with one adult) and 1:30–

3:00 p.m. (Ages 6–7, each child with one adult)

Imagine what it would be like to

live on a planet or moon with temperatures of -400 degrees Fahrenheit. In this workshop, investigate extreme cold in our solar system.

Robots in Space II (Intermediate)

Three Thursdays, 2/1–15, 4:00–5:30 p.m.

(Ages 8–10)

Continue your exploration of robotics by designing increasingly complex robots and completing ever more challenging missions.

Dr. Nebula's Laboratory: Life with Lucy

Sunday, 2/18, 2:00 p.m.

What would it be like to live, work, and play with Lucy, a three-million-year-old human ancestor? Come join Dr. Nebula's apprentice, Scooter, as she



ROSE CENTER FOR EARTH AND SPACE

Sets at 6:00 and 7:30 p.m.

Friday, February 2

Arturo O'Farrill Ensemble

The 7:30 set will be broadcast live on WBGO Jazz 88.3FM



JOHN ABBOTT



Lucy, an early human ancestor

explores the mystery, myth, and science of our earliest ancestors.

This program is made possible, in part, by an anonymous donor.

AMNH ADVENTURES: WINTER CAMPS

Monday–Friday, 2/19–23,

9:00 a.m.–4:00 p.m.

For further information, please call 212-769-5758.

Destination Space:

Astrophysics

(For 2nd and 3rd graders)

Have you ever wondered what it would be like to live, work, and travel in space? Join others who share your interest in astrophysics and learn more about the universe.

Robotics

(For 4th and 5th graders)

Design, build, and program your own robot to explore an unknown planet using Lego Mindstorms robotics kits and computers.



Astronaut Michael Gernhardt is attached to the space shuttle *Endeavour*'s robot arm during a spacewalk.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe

The Grand Tour

Tuesday, 2/6, 6:30–7:30 p.m.

This Just In...

February's Hot Topics

Tuesday, 2/20, 6:30–7:30 p.m.

Celestial Highlights

Welcome the Lions of March

Tuesday, 2/27, 6:30–7:30 p.m.

LECTURE

The Road to Reality

Monday, 2/5, 6:30–7:30 p.m.

Roger Penrose of Oxford University highlights his account of theoretical physics that does not shirk its mathematical foundations.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions

Journey into deep space—well beyond the calm face of the night sky—to explore cosmic collisions, hypersonic impacts that drive the dynamic formation of our universe. Narrated by Robert Redford.

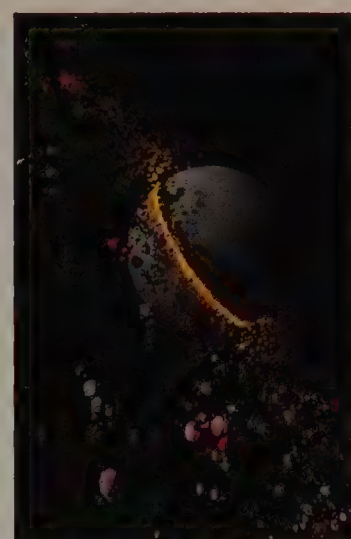
Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum. Made possible through the generous support of CIT. *Cosmic Collisions* was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

Sonic Vision

Fridays and Saturdays,
7:30 and 8:30 p.m.

Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamspace.

Presented in association with MTV 2 and in collaboration with renowned artist Moby.



Earth's Moon was created by a "cosmic collision."

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply.

All programs are subject to change.

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

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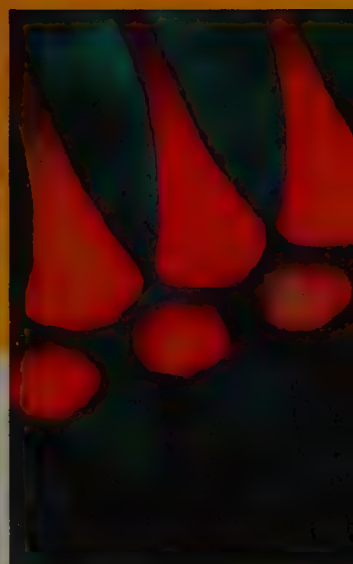
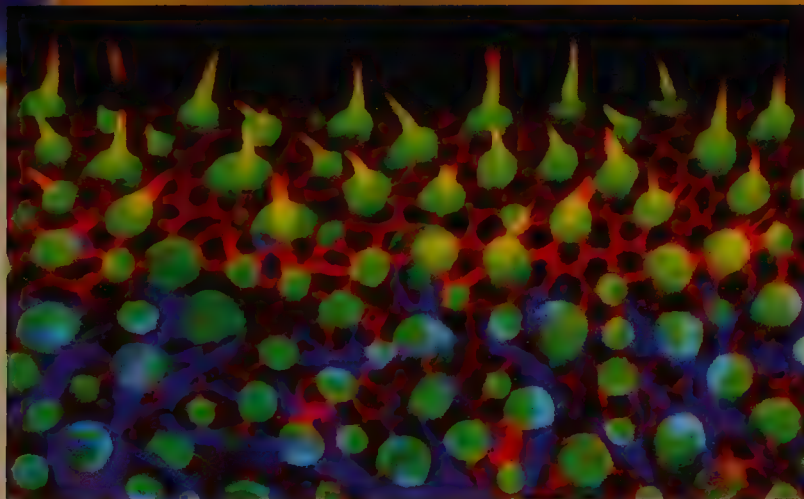


As winter deepens across much of the country, track the cozy climate indoors with this elegant version of a device originally conceived by Galileo in the 1600s. Housed in a cherry-wood stand, colorful spheres encased in glass rise and fall, indicating the ambient temperature of the room.




Small Is Beautiful

The often uneasy marriage between science and art can be positively blissful when it comes to photomicrography, or photography through a light microscope. Micrographs have become a powerful tool for scientific investigation, but the ones shown here—all honorable mentions in the Olympus BioScapes 2006 Digital Imaging Competition, organized by Olympus America, Inc. of Center Valley, Pennsylvania—reveal the artistic beauty in life's eclectic complexity.



Top: Stamen cells in the small pink flower of a *Tradescantia* plant undergo cytoplasmic streaming, the movement of organelles along microfilaments. The "tracks" show the organelles' paths. The image is magnified 700x. Above: Sensory hair cells (green) of a mouse's utricle, an organ of balance in its inner ear, appear in an image magnified 550x. Above middle: Longitudinal section of a rat fetus reveals its humanlike anatomy, including its tongue (blue), heart (green), and liver (right of heart, in blue). The image is magnified 3x. Above right: Cartilage in the ventral fin of a turbot, a flatfish, is shown in an image magnified 100x. Right: Regenerating bag cell neuron, which helps initiate the reproduction of a hermaphroditic sea slug (*Aplysia californica*). Thin projections called filopodia (pink), protruding ahead of the leading edge of the neuron (yellow), enable the cell to move. The image is magnified 300x.

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undertook the first
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EXPLORATION



Kikuo Morimoto
revived traditional
silk fabrication in
rural Cambodia.

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**Teresa Manera
de Bianco**
preserved prehistoric
animal tracks
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SCIENCE

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NATURAL HISTORY

3/07

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AMERICAN MUSEUM OF NATURAL HISTORY



Worlds to Discover...



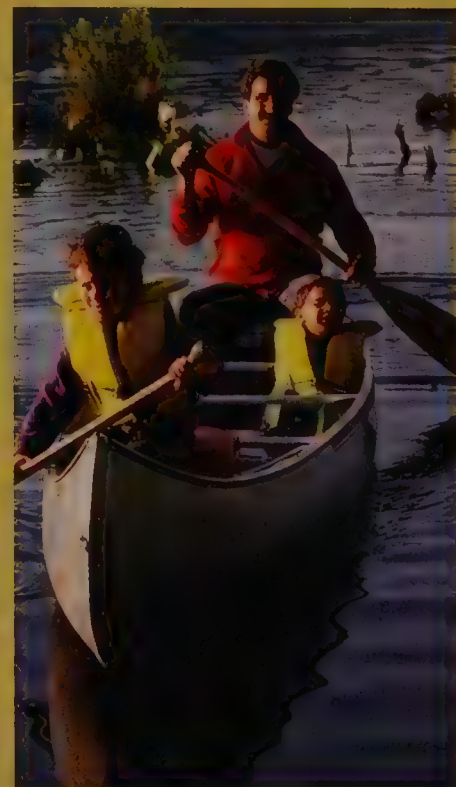
AMNH Expeditions Family Programs



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Members and friends of the Museum have been exploring the world on AMNH Expeditions for more than 50 years in the company of AMNH scientists and guest lecturers. Our diverse lineup of Family Programs is designed to engage, enrich, and delight all generations.

For a complete listing of our upcoming Family Programs and to book online, visit our website at amnhexpeditions.org or call AMNH Expeditions at 800-462-8687 or 212-769-5700



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VOLUME 116

NUMBER 2



COMMENTARY

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This fall, despite a public outcry, bears habituated to people in Alaska's McNeil sanctuary may be hunted on adjacent lands.

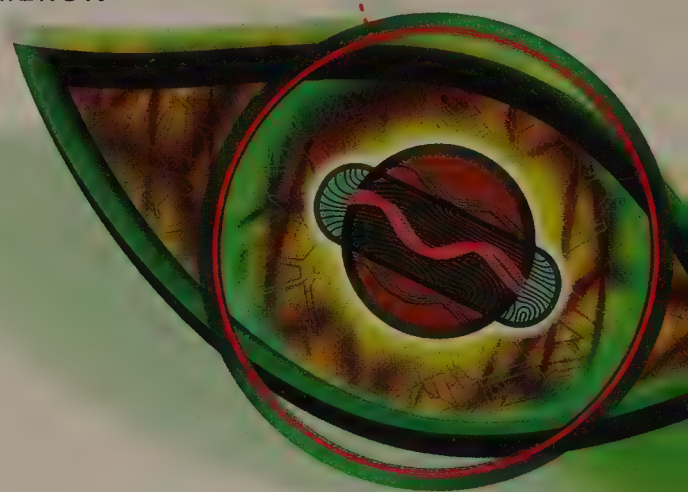
BILL SHERWONIT

FEATURES

52 BAR CODING FOR BOTANY

A system modeled on commercial bar codes may soon enable anyone to identify any plant from a small fragment of its DNA.

KENNETH M. CAMERON



COVER STORY

58 ON THE TRAIL OF THE ANCESTORS

Anasazi pueblos lie in ruins across the American Southwest. What became of their inhabitants?

CRAIG CHILDS

ON THE COVER: Doorway, with kiva and roof entrance, Mesa Verde National Park, Colorado. Photograph by George H.H. Huey

NATURAL HISTORY

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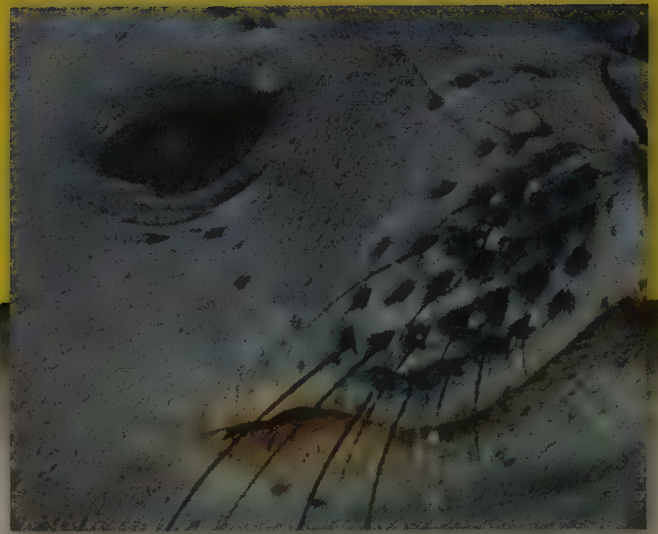
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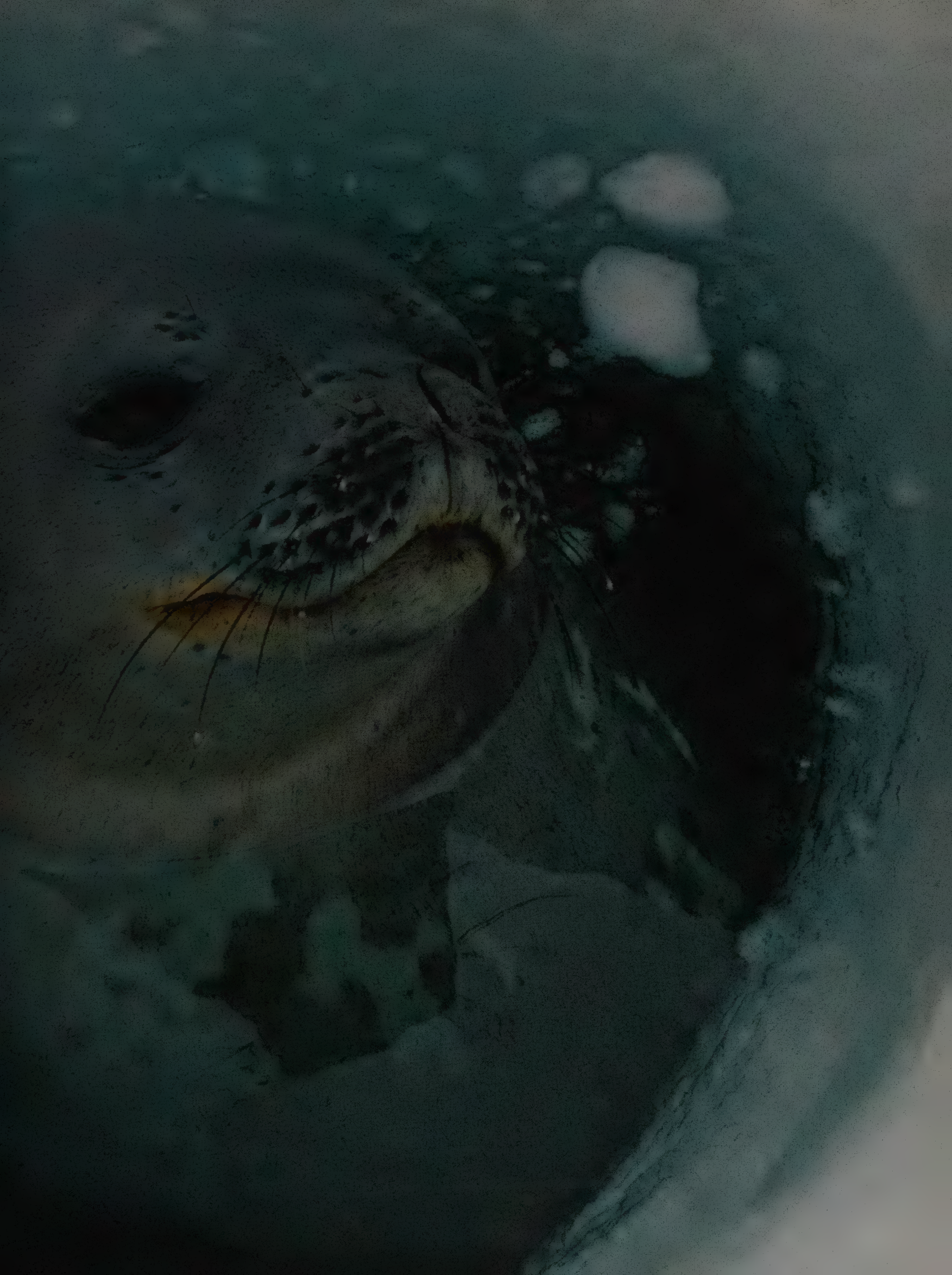
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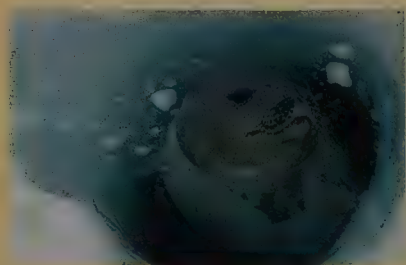
THE NATURAL MOMENT

Exit Strategies

Photograph by Tony Martin



◀ See preceding two pages



Even from across a field of sea ice crowded with emperor penguins, Tony Martin was startled when he spotted a lone Weddell seal shoot through what looked like solid ice. Martin, a zoologist with the British Antarctic Survey, began walking toward whatever crack or hole had allowed the seal to emerge from the Ross Sea below. Before he arrived, the seal slid back under the ice, leaving Martin to wait.

The portal proved to be about three feet across, its inner edges serrated from the gnawing of the seals' front teeth, a process known as reaming. In the summer months intense reaming isn't needed, because the ice is thinner and has more natural openings the seals can use to surface. But whether under thick or thin ice, Weddells are far from hindered under water: they can sleep, mate, or, most often, hunt for fish and squid.

On a hunt, Weddells can descend a quarter of a mile under water and hold their breath for more than an hour. On such dives the seals slow their hearts, decrease blood flow, and use oxygen stored in their muscles. Physiologists dream that genes for low-oxygen tolerance might one day help treat people with heart and lung diseases.

Martin experienced the seals' diving stamina firsthand, as he waited at the lip of the hole. After an hour of keeping vigil, he got a big surprise when a 500-pound seal launched itself out of the water "like a missile out of a submarine," and landed on top of him. Fortunately, the next seal to come up for air simply poked out its deceptively petite head.

—Erin Espelie

Killer App

Kenneth M. Cameron ("Bar Coding for Botany," page 52) imagines that one day soon, "global flora scanners" will catch bad guys who smuggle endangered plants across international borders. My vision is more benign: You've taken the day off to hike the woods in the early spring. Wet snow still fills the forest with cool, damp air, but the sun is bright, and up ahead, at a break in the canopy, a blossom is bravely forcing the new season. The flower is unfamiliar.

You unclip your handheld GPS unit from your belt. Stoop. Snip. You take a tiny bite of leaf with the hole punch, press "ID" on the keypad, and wait for the Hypernet response. Sure enough, the blossom is a rare, endangered blue-eyed Mary (*Collinsia verna*); no one has recorded the flower in these woods for twenty years. Immoderately pleased by your sharp eyes and good luck, you press "Record"; the system clock marks the time and date, the GPS module remembers the location, and the flower is filed in your personal database. Before you move on, you take a digital photograph of the flower, and dictate a few remarks into the digital recorder.

Behind this new technological magic is one of the most exciting biological projects since the sequencing of the human genome. The project, known as DNA bar coding, is an international effort to create a universal genetic database of life by sequencing short, species-specific regions of DNA from every living species on Earth. Among botanists, Cameron says, the goal is to identify two or perhaps three genes that occur in all plants, yet in combination are distinctive enough from species to species to serve as reliable species markers. Between now and an international meeting this September in Taiwan, of the Consortium for the Barcode of Life (CBOL), Cameron and his colleagues in the Plant Working Group are seeking as much peer review as possible before a recommendation is made about exactly which genetic markers will serve as bar codes in the database.

How long will it take to build the database? "Lots of people are chomping at the bit to get into this," Cameron says. The bar codes for the vast majority of land plants could be ready within a couple of years of CBOL's decision, he adds. At the same time, electronics and nanotechnology circles are buzzing about how the relevant bar codes would be "read" in the field. Presumably, Cameron explains, once the plant matter is sampled and dissolved, its DNA would be channeled along micro-etchings on a chip-size glass surface, where a sequence of miniature chemical reactions and embedded logic circuitry would look for the relevant genes. No one knows how long Silicon Valley will need to make a usable product, but given the pace of change, several electronic generations (that is, five or ten years) doesn't seem unreasonable.

• • •

Our regular "Biomechanics" columnist, Adam Summers, reaches a milestone with this issue. His column, "No Bones About 'Em" (page 36), about the advantages of having a cartilaginous skeleton, is his fiftieth for *Natural History*. That's a remarkable achievement for a scientist and professor still young enough to have a seven-month-old child at home. Congratulations, Adam!

—PETER BROWN

Legends of Fire Fighting



Average length of fire engine replicas: 5"



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1939 BEDFORD This stalwart was especially active in England during the Battle of Britain. This one, from Liverpool, had a 500 gpm pump.



LEYLAND CUB FK7 Built in 1936, the FK7 had an 80 horsepower, 6-cylinder engine, a 49 feet extension ladder and a 750 gpm pump.



1907 SEAGRAVE AC53

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CONTRIBUTORS

TONY MARTIN ("The Natural Moment," page 4) is a zoologist with the British Antarctic Survey, specializing in seabirds, seals, and whales. He has spent most of his professional life studying aquatic mammals and birds in the polar regions and in the Amazon. Lenses and a camera in his backpack accompany him on all his fieldwork, ready to capture an image such as this month's Weddell seal. Martin enjoys writing and lecturing about wildlife, and he is completing his sixth book, *Albatross*, which will be distributed in the United States by Voyageur Press.



Born in Bridgeport, Connecticut, **BILL SHERWONIT** ("Bad News for Bears," page 38) is a nature writer who has made his home in Alaska since 1982. He has contributed essays to a wide variety of publications, and he is the author of ten books about Alaska. Since the late 1980s he has visited McNeil River State Game Sanctuary several times, and has written extensively about the sanctuary, McNeil's bears and their protection, and the legacy of Larry Aumiller, who was McNeil's manager for thirty years. His Web site is www.billsherwonit.alaskawriters.com.

KENNETH M. CAMERON ("Bar Coding for Botany," page 52) spends his working hours in the Bronx as Cullman Curator and Director of the Lewis B. and Dorothy Cullman Program for Molecular Systematics Studies at the New York Botanical Garden. In the evenings and on weekends, however, he retreats to a one-room cabin on a lake in the Hudson highlands. His most recent previous contribution to *Natural History* was an article about his research specialty, the evolution and classification of *Vanilla* and related orchids ("Age and Beauty," June 2004). His work has been featured in *The New York Times*, *The Wall Street Journal*, and on the PBS television series *NOVA*.



A native of the American Southwest, **CRAIG CHILDS** ("On the Trail of the Ancestors," page 58) has long been stumbling across traces of the Anasazi, a prehistoric people who once flourished there. Inspired as well by the work of archaeologists in the region to learn more about the Anasazi, he set out to gather the threads of evidence that would explain their fate. The result is his forthcoming book, *House of Rain: Tracking a Vanished Civilization across the American Southwest*, which is excerpted in this issue and is being published by Little, Brown and Company. Childs's writings appear in magazines and newspapers, and he is a regular commentator for National Public Radio. His previous books include *The Secret Knowledge of Water: Discovering the Essence of the American Desert* (Sasquatch Books, 2000) and *The Desert Cries: A Season of Flash Floods in a Dry Land* (Arizona Highways Books, 2002). He lives in western Colorado with his wife and two young sons.

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LETTERS

Stars and Monuments

Donald Goldsmith's article on the "wandering" of the North Star ["Turn, Turn, Turn," 12/06–1/07] led me wonder, how did that wandering affect the orientation of ancient monuments, such as the Egyptian pyramids and England's Stonehenge, to astronomical features?

Ray Ortiz

Redwood City, California

DONALD GOLDSMITH REPLIES: Orientations would have differed, depending on the ancient builders' goals. The prevailing view about Stonehenge is that it was built primarily to mark sunrise at the summer solstice. To orient the structure, all the ancient builders had to do was note carefully the point on the horizon where the sunrise began its retreat southward. Precession does not affect that point.

In contrast, monuments built to orient toward a particular star would no longer point to that star after a few centuries. Only a complete cycle of precession would restore the original orientation.

A large literature deals with possible astronomical orientations of the pyramids. In my article I oversimplified, at best, in stating that the pyramid builders relied on Thuban as a north star (and I was apparently in thrall to a myth when I believed that a tunnel in the Great Pyramid aligns with it). K.E. Spence, an Egyptologist at the University of Cambridge, has argued that the pyramid builders used a combination of two stars, one on ei-

ther side of the north celestial pole: Kochab, a bright star in the Little Dipper, not far from Thuban, and Mizar, one of the stars in the handle of the Big Dipper. According to her hypothesis, slight variations in the northward orientation of various pyramids arose from the way precession affected the Egyptian surveyors' ability to determine true north with that method. If so, those varia-

and living organisms are essential parts of the soil, and particularly of the "biomantle"—the upper layer in which most underground organisms live and dig. They collectively impart a biodynamic to Earth's soil that is probably unique in the universe, and totally unlike, we believe, Martian soil, lunar soil, and the like.

Donald L. Johnson
University of Illinois
Urbana, Illinois



"We don't mind visitors, as long as you don't eat our porridge."

tions could help date the pyramids' construction.

Editor's Note: Donald Goldsmith's further reflections on precession and other motions of the Earth in space appear on page 14 ("Ice Cycles").

Soils: Alive!

One statement in Robert R. Dunn's delightful article "Dig it!" (12/06–1/07) deserves clarification. He writes: "When tunnels cave in, animals that are effective diggers can escape. Those that aren't, become part of the soil." Taken literally, that implies that animals and other organisms must be dead before they become part of the soil. But to soil scientists, both dead

Happy Birthday, Theophrastus

In his article, "Happy Birthday, Linnaeus" [12/06–1/07], Richard Conniff credits Linnaeus with being "the inventor of the system by which every living species gets its two-part scientific name." The actual origin of this binomial shorthand goes back more than 2,000 years, to Theophrastus, the original classifier of plants. When classical Greek knowledge was rediscovered in the fifteenth century, his convenient two-part naming system was revived. Thereafter a succession of botanists used it.

Tom Hoeber
Gold Hill, Oregon

RICHARD CONNIFF REPLIES: Although I said in my article that none of the methods advocated in the Linnaean system was completely original, editorial space prevented me from elaborating on the antecedents. So I am grateful to Tom Hoeber for correcting the unintended slight to Theophrastus.

Shark Etiquette

R. Aidan and Anne Martin's amazing article on white sharks ["Sociable Killers," 10/06] prompts me to ask about shark behavior I witnessed on a scuba diving trip in Palau. At a seamount, one shark was hanging vertically in the water over the peak while so-called cleaner fish cleaned it. Off to one side, at the base of the seamount, ten or fifteen other sharks swam in a circle. As soon as the cleaned shark swam away, one shark peeled away from the circle and swam up to be cleaned. We never saw any sign of conflict among the sharks about taking turns. Did size prevent the conflict?

Jennifer McIntosh
Pacific Palisades, California

R. AIDAN AND ANNE MARTIN REPLY: Cleaning stations are remarkable places on reefs, where many species of fishes suspend aggression and predation, and each individual waits its turn for tiny cleaners to pick off parasites or dead skin. Many species of sharks and rays queue and take their turn; size seems to have no effect on preferred access.

What intrigues us about Jennifer McIntosh's report is the vertical orientation of the sharks (which were most likely gray reef sharks). Many bony-fish clients adopt unusual postures while they are being cleaned, but sharks typically either lie on the bottom or swim more slowly so that the cleaners can keep up. Because sharks rely on dynamic lift to maintain position in the water column [see "No Bones About 'Em," by Adam Summers, page 36], it is not easy for them to reduce speed; where there are strong currents, it may be easier.

Froggy Went A-Hikin'
In "Living the High Life" [9/06], Kevin Krajick describes the discovery of tadpoles in ponds as high

as 17,700 feet in Peru's Cordillera Vilcanota. Assuming they came from lower-elevation ponds, what could have led at least one reproducing pair to ascend to such suicidal heights? And how could they have survived the ascent?

*Norm Condit
Staten Island, New York*

BIOLOGISTS TRACIE A. AND ANTON SEIMON REPLY: Three species of frog occur in the high alpine watershed of Sibinacocha, a large lake at 16,000 feet: the aquatic *Telmatobius marmoratus*, and two terrestrial species, *Pleurodema marmorata* and *Bufo spinulosus*. We have found the same three species at 17,200 feet in ponds that feed a small stream flowing into the lake. Thus the stream provides a con-

duit between the lake and the high ponds for all three species. No surface watercourses link those ponds to even higher ponds, and we have not observed *T. marmoratus* (the aquatic species) above that elevation.

In contrast, the two terrestrial species can migrate to higher ponds, and we have observed *P. marmorata* tadpoles at a cluster of small ponds at 17,700 feet. Because reaching those isolated ponds would require arduous traverses, it is plausible that they landed there by other means, perhaps as accidental passengers aboard birds or mammals.

Yet in two visits to the highest ponds we found no adults, which might indicate that adults only migrate to the high ponds seasonally to breed. The high ponds'

isolation may reduce the threat of predation for the adults, and the intense mid-day solar heating may accelerate the metamorphosis of tadpoles into adults. A more speedy metamorphosis would also reduce the tadpoles' chances of being eaten, and enable them to leave the seasonal ponds before they dry out. In any case, no one should assume that these well-adapted species find their environments inhospitable.

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400-Yard Dash

The Dead Sea Scrolls, biblical texts written sometime before A.D. 68, were discovered in 1947 in caves near the ruined settlement of Qumran on the Dead Sea. But who were the scrolls' scribes? Most scholars think at least some of them were members of an ancient Jewish sect called the Essenes who, they argue, lived at Qumran. Newly discovered evidence—of a decidedly worldly nature—bolsters that view.

Two of the scrolls instruct religious adherents to build communal latrines some distance northwest of their city. Furthermore, Josephus, a Jewish historian of the first century A.D., wrote that the Essenes were adamant about defecating in "retired spots" and burying their feces. Evidence of buried feces a good distance northwest of Qumran,

then, would connect the settlement, the Essenes, and the Dead Sea Scrolls.

Feces can't normally remain intact in the desert for hundreds of years. But the dead eggs of intestinal parasites can—so long as they are buried and thereby protected from sunlight and wind. A team led by Joe E. Zias, a paleopathologist at the Hebrew University of Jerusalem, sampled the soil in and around Qumran. In only one area did they discover eggs from human intestinal parasites. As predicted, the site was about 400 yards northwest of the village (a nine-minute uphill hike, Zias determined) and hidden from view behind bluffs.

Zias believes that the sect members, their mission accomplished, immersed themselves in



Fragment of Dead Sea Scroll (above); whipworm (left), an intestinal parasite, magnified 25X

a bath on their walk back down to the settlement. That sounds like a healthy practice, but the bathwater was anything but fresh: Qumran relied for water on runoff collected during a brief annual rainy season. Skeletal remains indicate a population in extremely poor health, possibly because disease-causing organisms were repeatedly carried from toilet to bath, where they flourished and infected new hosts. (*Revue de Qumran*) —Stéphan Reeb

Scent of a Moth

Female moths of the species *Utetheisa ornatrix* boost their chances of attracting a mate by pumping out sex pheromones in unison—the olfactory equivalent of chorusing frogs—according to new research. Hangkyo Lim and Michael D. Greenfield, both behavioral ecologists at the University of Kansas in Lawrence, tested females in the laboratory to find out whether they adjust their chemical signaling in the presence of other females. Females housed in groups began releasing pheromones sooner and continued to signal longer and with fewer interruptions than did isolated females. They also appeared to signal more vigorously: the group-housed females pumped their abdomens more rapidly, a behavior thought to enhance



Utetheisa ornatrix: girls compete for boys

the release of pheromones.

Until now, biologists had described sexual communication in moths largely as a straightforward interaction between signaling females and responsive males, which fly upwind toward the source of the pheromones they detect. Lim and Greenfield's findings, however, show that female *U. ornatrix* moths also keep track of what their competitors are doing, suggest-

ing that the story in that species is more complex.

Unlike the males of most other moth species, *U. ornatrix* males mate infrequently compared with females, because it takes the males several days to produce a spermatophore—a kind of insect prenuptial gift that carries nutrients, toxins

to ward off predators, and sperm. That valuable gift entices females to mate multiple times, another behavior unusual in moths. Those quirks lead to a circumstance fairly uncommon in nature: the sexually receptive females outnumber the males. Lim and Greenfield suspect that the competitive signaling behavior of *U. ornatrix* females stems from the surplus. (*Behavioral Ecology*)

—Nick W. Atkinson

The Chemistry of B.O.

Everyone has a special smell, often recognizable to other people and to dogs. New research, the most comprehensive study of human odor to date, shows that body odor is made up of a diverse array of volatile compounds. One's own distinctive scent, moreover, comes from a personalized blend of those chemicals.

A team led by Dustin J. Penn, an evolutionary and behavioral ecologist at the Konrad Lorenz Institute for Ethology in Vienna, collected samples of saliva, armpit sweat, and urine from nearly 200 people living in an Austrian village. Sweat, the team discovered, includes the greatest number of volatile compounds; the team counted 373 such compounds that subjects consistently produced throughout the ten-week study.

Each person produced his or her own subset of the compounds. The subsets overlapped, yet individuals were readily distinguishable. Unsurprisingly perhaps, men and women tended to produce different mixtures—though no single compound differentiated the sexes. The study provides a new method for measuring a person's baseline odor. Because body odor can change with the onset of illness, the method could lead to new ways of diagnosing disease. (*Journal of the Royal Society Interface*) —S.R.

SAMPLINGS

Cosmic Rain

Cosmic rays—charged particles emitted by supernovas and other highly energetic sources in space—continually strike the Earth's atmosphere. Most scientists, however, had assumed they could have little effect on terrestrial life. Then last year, Henrik Svensmark, a physicist at the Danish National Space Center in Copenhagen, published experimental evidence that cosmic rays could increase the formation of cloud droplets, with obvious implications for climate and thus for life. Now another study by Svensmark reveals a remarkable link between cosmic rays and the stability of biologi-

cal productivity on Earth.

Two main factors, Svensmark assumes, have accounted for most of the changes in Earth's cosmic-ray exposure through geological time: the amount of shielding from cosmic rays afforded by the Sun's magnetic field, and the rate of supernova formation throughout our Milky Way. Svensmark estimated the Sun's shielding by studying other sun-like stars for clues to our star's history, and the supernova rate from straightforward astrophysical records. He also estimated changes in Earth's biological productivity through time by

Hot gas cloud from a supernova, a cosmic-ray source

measuring the ratio of the isotopes carbon-13 to carbon-12 in ancient sediments. Life processes, such as photosynthesis, preferentially use carbon-12, so the higher the relative amount of carbon-13 left behind in sediment, the greater Earth's bio-

mass must have been when the sediment was deposited.

Svensmark discovered that when cosmic rays were most intense (between 2 billion and 2.5 billion years ago, for instance), life was particularly unstable: periods of high productivity alternated with leaner times. Thus a surprising connection exists between distant supernovas and life on Earth: intense cosmic rays appear to cause climate fluctuations that bring on alternating periods of feast and famine. (*Astronomische Nachrichten*) —S.R.

Double Trouble

Small fish on the coral reefs of the Red Sea face danger from all directions. Swimming in open water increases their chances of lethal encounters with hungry groupers, but hiding in a crevice exposes them to giant moray eels. It gets worse: a new study shows that the little fish's pursuers are in cahoots.

Redouan Bshary, a behavioral ecologist at the University of Neuchâtel in Switzerland, and three colleagues discovered that groupers shake their heads in a distinctive way to invite moray eels to leave their lairs and join the search for prey. The predators then set off together to patrol the reef; the eel sneaks through the rocks while the grouper waits to intercept fleeing prey. Similarly, the team found, if a grouper hunting solo chases its target into an inaccessible



Hunting buddies: grouper (above) and giant moray eel (right)

coral fissure, it sometimes gives a slightly different headshake to mobilize a nearby eel.

Cooperative hunting between species had previously been noted only in humans hunting with dogs or dolphins. Even cooperative hunting among members of the same species

is limited to a handful of mammals and birds, animals with relatively strong cognitive abilities. But Bshary's study shows that the active collaboration between groupers

and eels increases hunting success—for the groupers, at least—by as much as a factor of five. Once caught, prey are never shared, but Bshary's group thinks the

selfishness is actually the key to success because it eliminates competition for the kill. So long as both species benefit from the arrangement in the long run, it doesn't matter which hunter happens to catch a particular fish. (*PLoS Biology*) —N.W.A.

Basso Profundo

Blue whales, the biggest creatures on Earth, have the deepest voices: most of their vocalizations are pitched far too low for people to hear. Their songs repeat a series of eerie tones, blips, and creaks and may carry on for hours or even days. To human ears, the alien, barely audible songs are all but indistinguishable. A new study shows, however, that the leviathans sing

several variations on the "blues," each correlated with a particular region of the sea.

Mark A. McDonald, an acoustician at Whale Acoustics, a company in Bellvue, Colorado, and two colleagues examined thousands of sound spectrograms computed from blue-whale songs recorded around the world since 1959. They found they could visually classify the spectrograms into nine distinct groups, each corre-

sponding to a particular geographic region.

Blue whales of both sexes make short calls, but only the males are known to sing, suggesting the songs may enable them to attract mates or advertise their presence to other males. (Under certain conditions their songs can travel thousands of miles, communicating to other whales across vast ocean distances.) If so, each song group may be characteristic of a particular blue-whale popula-

tion: after all, mating calls should attract compatible mates.

Songs, McDonald's team proposes, could become a convenient, noninvasive, low-cost way for biologists to keep track of blue-whale populations and subspecies—though distinguishing animal groups by their behavior instead of their physical or genetic characteristics remains controversial. (*Journal of Cetacean Research and Management*)

—Rebecca Kessler



Warm Down, Cool Up

Many satellites orbit Earth in the thermosphere, between sixty and 500 miles above the surface. Air is pretty thin up there, of course, but in the long run it's enough to make satellites slow down and fall to a lower orbit, a phenomenon known as orbital decay.

Orbital decay has been less pronounced in recent years, and that can mean only one thing: the thermosphere is thinning, which in turn means it's cooling. Here's where the story strikes closer to home. By burning fossil fuels people have been releasing ever more greenhouse gases—carbon dioxide (CO₂), in particular. And though CO₂ warms the lower atmosphere, it cools the thermosphere, because at those rarefied heights it converts the energy of collisions with other molecules to heat that radiates into space.

Liyang Qian and Stanley C. Solomon, both atmospheric scientists at the National Center for Atmospheric Research in Boulder, Colorado, and two colleagues have taken advantage

Northward Bound

Many bird species in the United States are shifting their breeding ranges northward, a new study shows. Similar northward shifts have been observed in Great Britain, so the cause of both is probably the same. Global warming is the likeliest suspect.

The new study comes from data gathered by the Breeding Bird Survey (BBS), a program run by the U.S. Geological Survey and the Canadian Wildlife Service. Each year, skilled birders spend a summer day driving or walking along more than 4,100 road seg-

ments of the U.S. and Canada, identifying the bird species they hear or see along the way. Because the survey has continued uninterrupted since 1966, its data enable ornithologists to analyze long-term population trends.

Alan T. Hitch and his graduate adviser, Paul L. Leberg, a conservation biologist at the University of Louisiana at Lafayette, report that out of twenty-six southern-U.S. species they studied in the BBS records, nine have significantly pushed the northern limits of their breeding ranges northward since the late 1960s. The northward shifts vary from twenty-six miles for summer tana-

ments of the U.S. and Canada, identifying the bird species they hear or see along the way. Because the survey has continued uninterrupted since 1966, its data enable ornithologists to analyze long-term population trends.

Each year, skilled birders spend a summer day driving or walking along more than 4,100 road seg-

of satellite tracking to test a computer model of how the thermosphere responds to input energy. In their model, the investigators calculate how much the thermosphere has cooled in the past thirty years by estimating the contributions of two factors: variations in solar activity (which warms the thermosphere directly) and changing levels of CO₂. They found good agreement between their

model and the temperature as measured independently by satellite orbital decay. Their model confirms that CO₂ has indeed cooled the thermosphere, and it predicts a further cooling of 3 percent by 2017.

If the useful lifetimes of satellites depended on physics rather than on budgets, maybe excess CO₂ would be good for something, after all. (*Geophysical Research Letters*) —S.R.



Great-tailed grackle

gers to more than 200 miles for great-tailed grackles. At the same time, the northern limits of only two of the twenty-six species, Bachman's sparrows and Bewick's wrens, have retreated southward.

Hitch and Leberg say the diversity of the nine southern species shows they are not being drawn northward by some specific factor in the midlatitudes—more bird feeders, for instance. Nor are their ranges simply expanding. If that were the case, northern species should have expanded their ranges southward, too, and there was no systematic indication of that. Instead, rising temperatures seem to be nudging southern ecosystems northward. (*Conservation Biology*) —S.R.

Concrete Evidence

How the ancient Egyptians built the Great Pyramids of Giza nearly 5,000 years ago, using only manpower and copper tools, is one of Egypt's enduring mysteries.

Their most impressive creation, the pyramid of Khufu, stands forty-five stories tall and is made up of some 2 million massive, three-ton blocks, some of which fit together flawlessly.

Most Egyptologists think crews of workers cut the blocks

from nearby limestone quarries, carved them with copper chisels, and hoisted them into place with immense ramps, levers, and wedges. But the absence of supporting evidence—no ramps, tools, or limestone waste piles remain—has given rise to alternative, and often controversial, explanations.

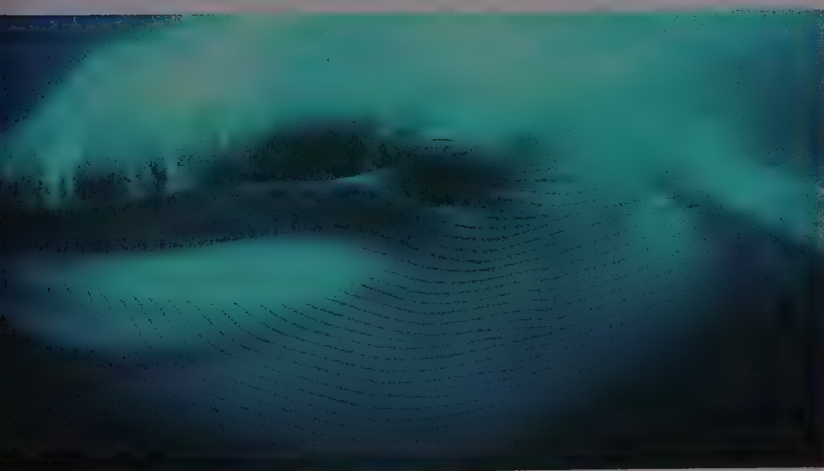
Now Michel W. Barsoum, a materials scientist at Drexel University in Philadelphia, and two colleagues have discovered evidence that could finally settle the issue—though in the meantime it has certainly fueled debate. The team examined samples from two pyramids at Giza and from local limestone formations with an electron microscope and analyzed the samples chemically. Their results support a two-

decade-old idea: parts of the Great Pyramids were built not of carved limestone blocks but of concrete casts.

In ancient Egyptian concrete, Barsoum says, limestone particles were mixed with a silica-rich binder. The ingredients could be transported in manageable quantities, then poured on site.

If confirmed, Barsoum's discovery will burnish the already impressive reputation of Egyptian builders: they would get credit for inventing concrete. And their recipe may point toward a clean, inexpensive, long-lasting substitute for portland cement, which is widely used today but highly polluting. (*Journal of the American Ceramic Society*)

—Graciela Flores



Ice Cycles

Long-term fluctuations in ocean temperatures lend support to Milutin Milankovitch's theory of climate change. But can his theory account for the ice ages?

By Donald Goldsmith

People at war rarely focus on theories of climate change. During the first half of 1941, while the Second World War was raging in Europe, a little-known Serbian engineer and mathematician published a book about ice ages. Milutin Milankovitch was then living in the Yugoslav capital, Belgrade, shortly before the Nazis invaded the country. In his book, translated as *Record of Radiation on Earth and Its Application to the Problem of Ice Ages*, Milankovitch strove to connect the cycles of ice ages on Earth to small changes in our planet's motions in space. The world wasn't listening, arguably for good reason.

Historical bad luck caused Milankovitch's book to appear at the wrong time, in the wrong place, and in the wrong scholarly language. At first his book made little impression on climate scientists in England and the United States, where most of the action was in climatology. Several decades passed before many investigators took his ideas seriously, and several decades more before they had amassed enough data to verify that his planetary-motion cycles seem to agree with the overall record of climate change on Earth during the past few hundreds of thousands of years.

Yet today, as climate change caused by human activities is being recognized as one of the most pressing problems of our age, long-range climate studies of all kinds deserve scientific attention. And because the Milankovitch cycles in Earth's climate record appear to be

real, they merit a closer look, if only to understand how to factor them into or out of predictions of what will happen climatically in the next few decades.

The concept of a linkage between periodic changes in the Earth's motions and the alternation of ice ages with warmer periods originated with James Croll, a Scottish amateur astronomer active during the third quarter of the nineteenth century. Although Croll lacked the more exact knowledge that later calculations would provide, he perceived that the Earth changes its orientation and orbit over periods of tens or hundreds of thousands of years, roughly the time (as then estimated) between ice ages. Milankovitch seized on Croll's ideas, performed extensive calculations of the changing amounts of solar heating that the cycles would produce, and claimed to have demonstrated a correlation between those celestial variations and changes in the Earth's climate.

Milankovitch concluded that the true causes of ice ages reside in the effects arising from periodic changes in three quantities that describe the Earth's motions in space. Those three quantities, each varying according to its own schedule, are: the angle by which our planet's rotation axis tilts from being perpendicular to the plane of the Earth's orbit around the Sun; the "eccentricity," or amount by which the orbit deviates from perfect circularity; and the timing of the seasons with respect to the point on the



Earth's orbital path closest to the Sun, which slowly changes because of the precession, or wobble, of the Earth's rotation axis. All three changes arise from the gravitational effects of other planets in the solar system, among which Jupiter, by far the most massive, has the greatest effect.

An understanding of the possible effects of those changes on the Earth's climate begins with the ways in which they can affect the rhythm of the seasons, the cycle that causes the most fundamental, and the most obvious, variations in the Earth's climate. The cycle of the seasons arises from the tilt of our planet's rotation axis. Because the axis points in nearly the same direction in the sky (currently almost toward the star Polaris) throughout the Earth's yearly orbit, the tilt of the axis alternately exposes the planet's Northern and Southern hemispheres to more direct sunlight as the year progresses. As of the year 2000 this tilt was 23.44 degrees.

The first of Milankovitch's cyclical

changes is a small oscillation in the tilt of the Earth's rotation axis. Over a period of approximately 40,000 years, the tilt varies between 21.5 and 24.5 degrees, with an average slightly less than its current value [see *lower diagram on next page*]. When the tilt gets smaller—and that's the current trend, which will continue until about the year 11,800—the difference between summer and winter in each hemisphere becomes less pronounced. The contrast makes little difference in the tropics, but at higher latitudes a smaller tilt leads to cooler summers and warmer winters. Cooler summers bring less melting of high-latitude snowfall, and that effect overshadows any reduced snowfall resulting from warmer winters. Hence the declining tilt tends to favor the onset of ice ages.

The second of Milankovitch's cycles deals with the eccentricity of the Earth's elliptical orbit. Eccentricity measures how much the shape of an ellipse deviates from being a perfect circle. The eccentricity of a circle is zero; as the

eccentricity of an ellipse rises toward 1, the ellipse becomes progressively more elongated. (Formally, the eccentricity is equal to the distance between the two foci of the ellipse, divided by the length of the long axis.) All the planets of the solar system with the exception of Mercury (and Pluto, if you still count it as a planet) have orbital eccentricities less than 0.1. For the Earth's orbit, the eccentricity varies between 0.005 and 0.058, (with a current value of 0.017) [see *upper diagram on next page*]. The complete cycle takes about 100,000 years.

Although the changes in the Earth's orbital eccentricity do not alter the length of the year, they do change the distances to the Sun from the closest and most distant points along the Earth's orbit. The annual variations in the Earth-Sun distance are small—and they certainly don't cause the seasons—but they do have a marginal effect on the amount of solar heating received on Earth at various times of the year. Consequently, the changes in eccentricity produce subtle, but no-



The Flat Earth Society says this is one of the four corners of the world.

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Eccentricity of the Earth's elliptical orbit (its deviation from circularity) around the Sun changes periodically over a cycle of 100,000 years. At certain points in the cycle the orbit can barely be distinguished from a circle, but at others the orbit becomes more elongated (a change that is exaggerated here for clarity). The changes in shape cause small variations in the amount of solar heating on Earth.

ticeable, changes in the strength of the seasonal variation on Earth.

The third of Milankovitch's cycles arises from the combined effects of two kinds of precession. The first is the precession of the Earth's rotation axis, a slow wobble of the imaginary line through the Earth's north and south poles that extends against the sky. The wobble causes that line to trace a circle on the sky once every 26,000 years [see

"Turn, Turn, Turn," by Donald Goldsmith, December 2006/January 2007], and so it slowly changes where the seasons fall with respect to the Earth's position in its orbit. For example, the summer solstice in the Northern Hemisphere now takes place when the night sky looks as it does on about June 21. But because of the precession of the axis, that solstice will arrive slightly "earlier," with respect to the stars, with each succeeding year.

The second kind of precession is vaguely reminiscent of an incredibly slow hula hoop gliding around the Sun. Astronomers call the hula-hoop motion "orbital precession"; it causes the Earth's perihelion, the point along our planet's orbit closest to the Sun, to slide around the Sun at a rate of about once every 110,000 years. The Earth now reaches perihelion in early January. But its orbital precession moves the perihelion in the direction opposite to that of the tilt-induced precession of the seasons. So the Earth reaches perihelion a few days "later," with respect to the stars, with each passing millennium.

The combined result is to speed up the rate at which the seasonal milestones are moving along the orbit with respect to the perihelion. The full cycle of the precession of the seasons through the perihelion is not 26,000 years—one cycle of the precession of the axis—but rather 21,000 years. That combined motion is the third of Milankovitch's cycles.

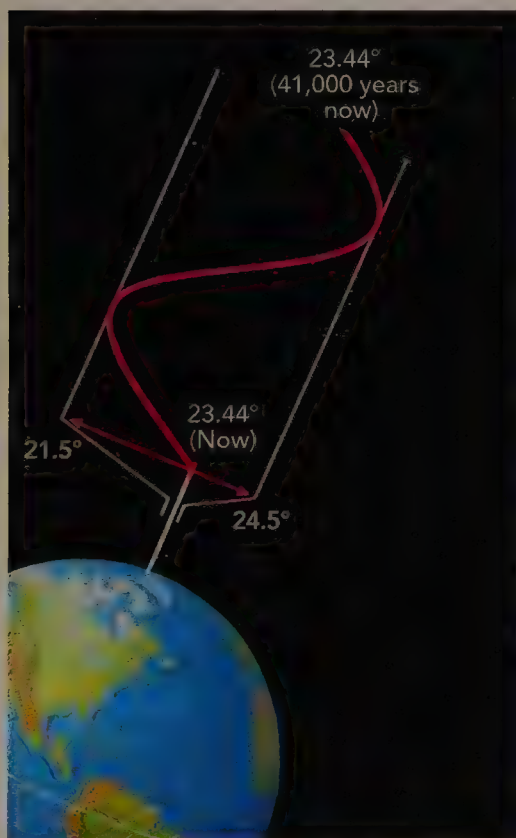
How could that third cycle make a difference to the Earth's climate? The difference arises from the fact that the Northern Hemisphere has far more

land than the Southern, and land masses react much more rapidly to temperature changes than oceans do. As a result, subtle differences in the yearly cycle of solar heating arise from having first one, then another, hemisphere closer to the Sun during a particular season. Since the Earth now makes its closest approach to the Sun in the northern winter, and is farthest from the Sun in the northern summer, both winters and summers are somewhat milder in the Northern Hemisphere than they are in the Southern. The more severe seasonal swings of solar heating in the Southern Hemisphere, however, are mitigated by the temperature-stabilizing oceans.

At a time a bit less than halfway through the 21,000-year cycle, in about the year 11,700, the combined effects of orbital precession and the precession of the axis will bring the Earth closest to the Sun on the summer solstice in the Northern Hemisphere. Then the extremes of temperature will be hemispherically reversed. Winters and summers in the Northern Hemisphere will become more extreme, and those effects will be amplified by the temperature-sensitive landmasses. Meanwhile, the seasonal swings of solar heating in the Southern Hemisphere will be milder, and made milder still by the climatic inertia of the Southern Ocean. Overall, the differing proportions of land and ocean in the two hemispheres can subtly amplify or dampen how the precessional changes modify the Earth's seasons.

In short, three cycles, recurring approximately every 40,000, 100,000, and 21,000 years, could periodically alter the solar radiation that reaches various places on Earth. All three result from the combined motions of the Earth, Sun, Moon, and planets, as they tug at one another in a gravitationally induced ballet. Milankovitch's great question can now be explored: What do these three cycles imply for the Earth's climate?

If climatologists possessed a complete record of all climate change on our planet—temperature, rainfall, sea level,



Tilt of the Earth's rotation axis is responsible for the annual cycle of the seasons. The axis currently makes an angle of about 23.44 degrees from the perpendicular to the plane of the Earth's orbit around the Sun, but the amount of tilt regularly cycles to and fro over a period of 41,000 years. The variation is greatly exaggerated here for clarity.

cloud cover, and other factors—they could, with an appropriate computer program, determine whether significant changes take place in sync with any or all of the three Milankovitch cycles. In reality, only partial and often uncertain records exist, primarily of the history of temperature changes in the world's oceans.

The most useful tool for obtaining the history of temperatures comes from the fact that oxygen atoms occur primarily in two isotopic forms, oxygen-16 and oxygen-18. Oxygen-16 is the commoner and lighter of the two, so when it binds with two hydrogen atoms in a water molecule, that molecule more readily evaporates. By contrast, when the heavier isotope, oxygen-18, forms a water molecule, it tends to fall as rain or snow more readily out of the sky.

Those differences become more pronounced as temperatures decrease. By the time water evaporated from the oceans is carried by the atmosphere to the cold, polar regions, it arrives

deficient in oxygen-18. In a complementary way, seawater grows richer in oxygen-18, compared with oxygen-16, at lower temperatures.

Paleogeologists who seek to reconstruct the history of the oxygen isotopes in ice have secured mile-long ice cores from Antarctica, whose water molecules hold abundant oxygen. They have also measured the changing abundances of oxygen isotopes in the fossils of miniature creatures called foraminifera, whose shells incorporate the oxygen atoms from the water that the creatures inhabited. Sedimentary layers of rock sprinkled with fossils of foraminifera record the history of oxygen in the oceans.

With that data in hand, all that remains is to assign dates to the manifold layers in the ice cores (recorded in the seasonal alternation between greater and lesser snowfall) and in sedimentary rocks. The changing relative abundances of the oxygen isotopes in each layer can then reveal how ocean temperatures have changed with the march of time.

By now, investigators have laboriously counted through the past few thousand years of ice cores and estimated the dates for even older ones.

To peer even farther back in time, paleogeologists date sedimentary rock layers, relying primarily on the history of reversals in the polarity of the Earth's magnetic field. That history has been independently determined from studies of other rock layers that record the same magnetic reversals, whose ages have been determined by radioisotope dating. By comparing ice cores and sedimentary layers from various places around the world, paleogeologists can verify that they are measuring global rather than local changes in climate.

Ice cores take the history of the Earth's temperature back through most of the past million years; the foraminifera in sedimentary rocks provide less accurate but still highly useful data back about 200 million years ago. Other techniques add to those results. For example, the geologists Paul



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E. Olsen and Dennis V. Kent of Columbia University's Lamont-Doherty Earth Observatory in Palisades, New York, have reconstructed the history of rainfall changes over continental landmasses, supplementing the isotopic data for rainfall changes over the oceans. They discovered that the sedimentary records from ancient lake beds can serve as rain gauges, because dry and wet epochs left sediments of differing colors. Rainfall records in lake sediments, which stretch back 235 million years, offer the chance to find cyclical changes that should correlate with the temperature changes measured from ice cores and sediments.

In an ideal world, those approaches would combine to yield an unambiguous answer to the question of how much the changes in solar heating from each of Milankovitch's three cycles—tilt, eccentricity, and precession—affect the Earth's climate. In practice, the “signal” of any such effects, if it exists, is buried in the “noise” of the incomplete and imperfect climate record. To find any such signal, investigators rely on statistical methods, but the challenges are formidable. To their credit—and in accord with the finest traditions of science—the difficulties have not stopped them from making the attempt.

So far as climatologists can now discern, the prize for best-demonstrated Milankovitch cycle goes to the 100,000-year eccentricity cycle. That cycle—at least for the past million years—correlates best with the history of temperature changes. The other two, the 40,000-year and 21,000-year cycles, also appear in the temperature record, but with less certainty. To add to the confusion, when climatologists look back through the much longer, though less well established, record of the past few hundred million years, they find that this statement no longer holds true. Instead, a 400,000-year cycle of variation in eccentricity—a complication I had hoped to spare the reader—appears dominant.

Those results illustrate the basic challenge that climate scientists face: to understand, and thus to predict, whether climate will change, and by how much, as a result of the various influences on our planet. “Climate is the ultimate black box,” Kent likes to say—meaning that climate experts still can't calculate the details of climatic “output” from “inputs” such as solar heating.

For example, the study of global warming in the past few decades has made climate scientists all too well aware that tremendous feedback effects can arise from even small changes in

Given the difficulties of understanding present-day climate effects, reconstructing what affected climate a million years ago seems nearly impossible.

the amounts of greenhouse gases in the atmosphere. Consider methane: predicting its rise or fall in the atmosphere is a daunting task. The reason is partly that its sources are as diverse as bacteria in rice paddies and the digestion of bovines, and partly that it is such a strong greenhouse gas: twenty times as efficient as carbon dioxide at trapping heat from the Earth's surface in the atmosphere. Given such difficulties in understanding the present-day climatic effects of methane, reconstructing the methane budget of a million or a hundred million years ago seems nearly impossible. The connection between small changes in solar heating on Earth and the climate changes that they may induce remains a puzzle largely unsolved.

Similarly, even though the reality of the Milankovitch cycles seems well established, climatologists still don't understand exactly how our cosmic habitat affects our climate. Milankovitch's hypotheses stands in a position analogous to that of Alfred L. Wegener's

“continental drift theory” in 1960, half a century after Wegener proposed it. At that time, the evidence for continental motions seemed intriguing (and had been noticed before Wegener proposed his theory). Once earth scientists realized that seafloor spreading can explain how and why the continents move, Wegener's theory gained relatively rapid acceptance.

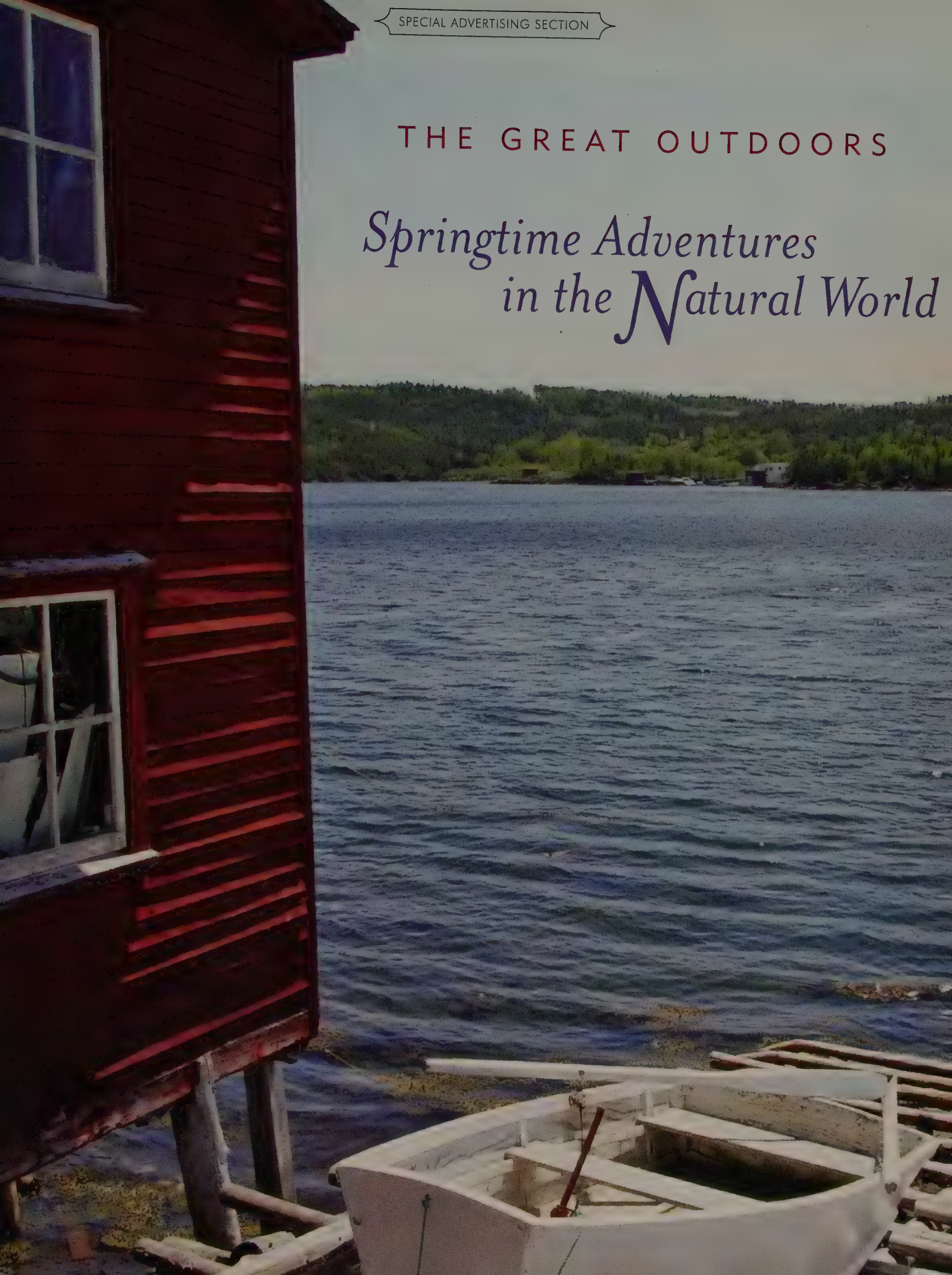
Like the geologists of Wegener's day, climate scientists can appreciate “bare facts” as well as anyone. Certainly climatologists are aware that small changes in solar heating arise from cycles of planetary motion; more precisely, they can calculate the small variations that arise from differences in solar heating throughout the Milankovitch cycles. But they cannot explain clearly enough how those variations can affect Earth's climate so strongly that an ice age arises or recedes. Some day, they may attain that understanding—or perhaps deeper insights into climate changes may lead to the rejection of Milankovitch's hypotheses.

Meanwhile, the theory of Milankovitch cycles has the virtue of making a definite prediction. Setting aside all effects of human activity on climate, Earth should be currently on a temperature downslope, growing ever cooler in the next 5,000 or 10,000 years. Sad to say, though, the present release of carbon dioxide, mainly through the burning of coal and oil, overcompensates for any cooling trend by several orders of magnitude. As clearly as anyone can peer into the future, human-generated global warming at today's rate will be enough to offset all the Milankovitch cooling of the next five or ten millennia in a single generation. It seems unlikely that nature will save us from ourselves.

DONALD GOLDSMITH is the author of twenty books on astronomy, including *Connecting With the Cosmos* (published by Sourcebooks in 2002). He is the co-author, with Neil deGrasse Tyson, of *Origins: Fourteen Billion Years of Cosmic Evolution* (Norton, 2004).

THE GREAT OUTDOORS

Springtime Adventures in the Natural World





Peru boasts ten thousand years of history and ancient cultures, a rich colonial tradition, and an extraordinary variety of wildlife

THINK OF PERU AND THE FIRST THING that comes to mind is the wealth of its age-old cultures and the legendary Inca empire.

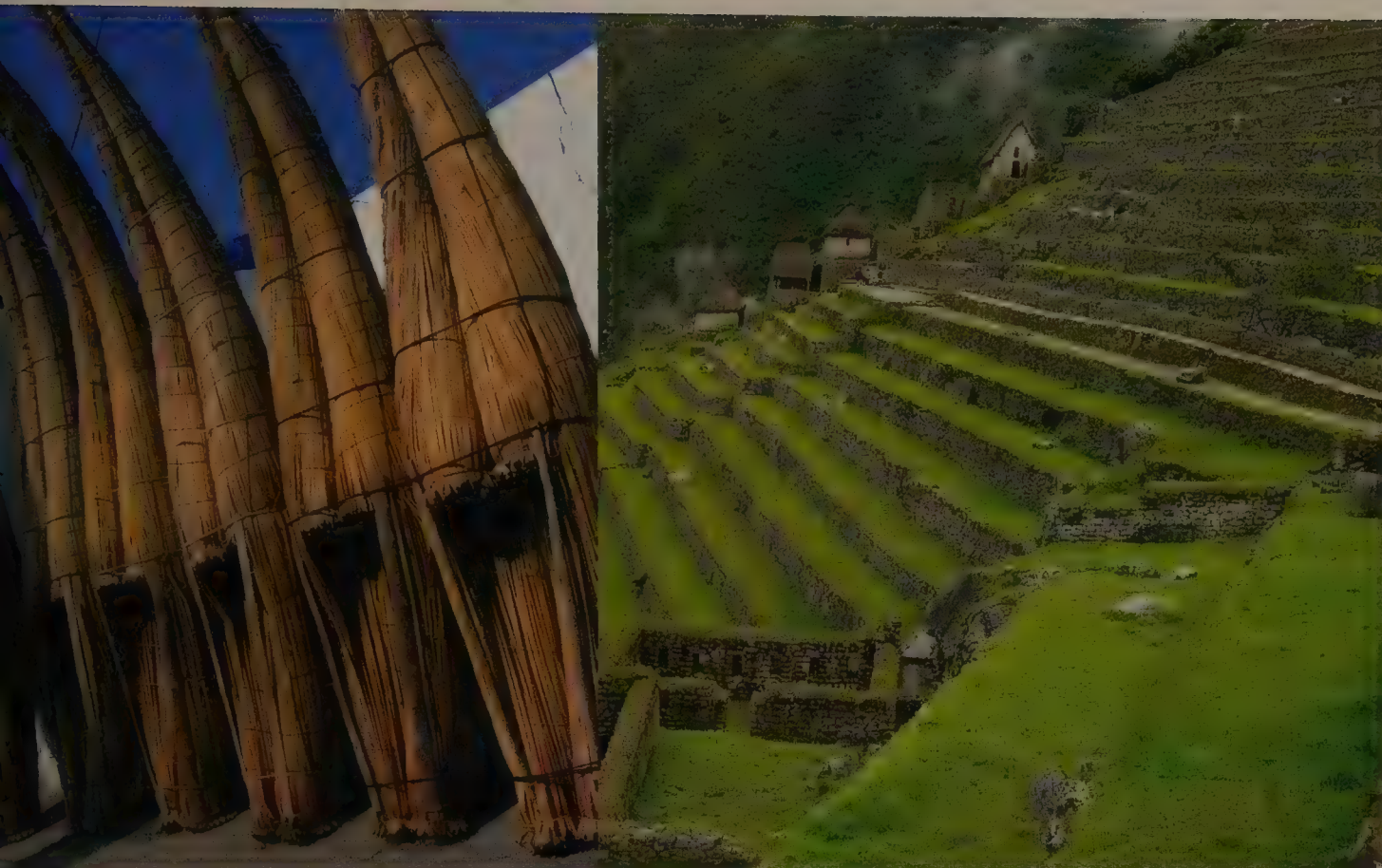
The city of Cusco, the ancient capital of the Inca, is lined with narrow, cobblestone streets and Inca buildings. Cusco's Inca roots and colonial buildings placed it on UNESCO's World Cultural Heritage List in 1983. The Koricancha, the luxurious and sacred Sun Temple, just yards from the city's main square, was built in honor of Inti, the sun god, and its walls were once covered with gold. North of the square you'll find the palace of Inca Roca, which housed the sixth Inca governor. Some believe that the Incan city was built in the shape of a puma, or mountain lion, which squatted over the Saphi River; as evidence they point to street names that translate to "puma's spinal column," "puma tail," and other names designating parts of the animal's body. The Spanish conquistadors

arrived in Cusco in 1533, and scattered amid the Inca sites you'll find Andean Baroque structures that preserve the legacy of this colonial period, such as the ornate Cathedral and the Church of the Company of Christ.

Don't miss the picturesque neighborhood of San Blas, where the best artisans in the city have set up their workshops. After hours, this magical city has an exciting nightlife with cafés, restaurants, and bars for all tastes. Just ten minutes away from the city, you can see the massive walls of the Sacsayhuamán fortress, and a few miles from there, you'll find the archeological sites of Qenko, Pukapukara, and Tambomachay, Incan buildings constructed completely with stone.

The most famous Inca site—and Peru's most visited attraction—is the Machu Picchu Historical Sanctuary. You can reach Machu Picchu via a scenic, three- to four-hour train





ride from Cusco, or better yet, get there by hiking the Inca Trail. This walking route through the mountains above the Urubamba River traverses ruins, a cloud forest, and rich subtropical jungle. The forty-five-kilometer trail, built along an old Inca roadway, takes about four days to complete. Machu Picchu (which means "old mountain" in Quechua, the Inca language) stands atop a mountain high above the Urubamba. A center of worship as well as an astronomic observatory, it was the private retreat of the Inca ruler Pachacútec and his family. The site has two major areas: an agricultural zone, made up of terraces and food storehouses; and an urban zone, with ornately carved temples, squares, and royal tombs. Stone staircases and canals are found throughout the city.

Because of its location in the cloud forest, Machu Picchu is home to unique species of flora and fauna, including the cock-of-the-rocks (Peru's national bird); the spectacled bear, the only bear species in South America; a rare dwarf deer called sachacabra; and the Huemal deer. In addition to more than 300 bird species (including the Andean condor and numerous hummingbirds), the site boasts some 200 recorded species of orchids. The

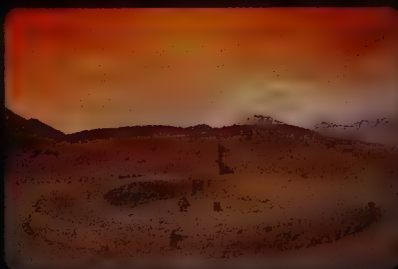
best times to visit Machu Picchu are during the dry season, from April to September.

Don't leave the Cusco area without a visit to the Manu National Park, a nature lover's paradise in the Amazon Basin. Manu hosts more than a thousand species of birds, 1,200 butterfly species, over 20,000 plants, and innumerable insects, amphibians, and reptiles.



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Citadel of Caral

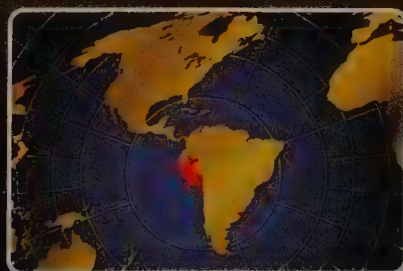


Inca Uchabamba Doorway

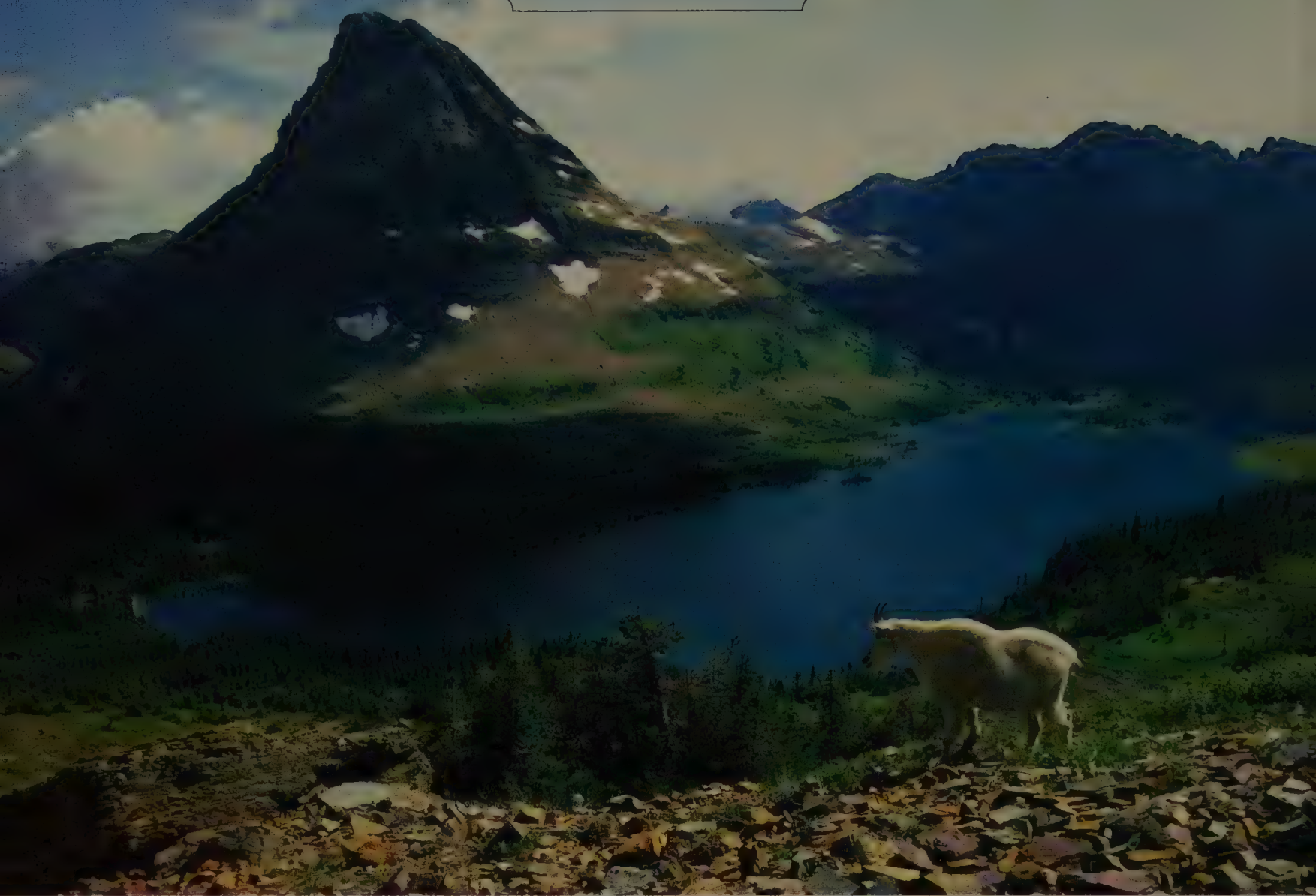


Pyramid of the Sun and of the Moon

Chan Chan (Trujillo), the oldest mud city in the Americas



www.peru.info



Mountain goat reigning over Glacier National Park

Rodney Schlecht

Think of Montana as a giant, natural animal preserve

MONTANA HAS TONS OF FAMOUS SITES and sights you'll want to visit, such as Glacier and Yellowstone National Parks and numerous stops along the Lewis & Clark Trail. But off the beaten path, you'll find fantastic birding, one-of-a-kind dinosaur digs, remarkable scenic drives, and plenty of wildlife.

Montana has over 400 known species of birds, attracted by diverse habitats, from alpine zone at Glacier National Park to desert scrub, sagebrush steppes, and shortgrass prairie. Birdwatchers will appreciate the Bitterroot Birding and Nature Trail, one of the first completed trails in a planned statewide network, comprising 25 of the top nature sites between Lost Trail and Lolo Pass. The marshes

of Red Rocks Lake National Wildlife Refuge are filled with the largest population of trumpeter swans in the lower 48 states. Along the Rocky Mountain Flyway, more golden eagles have been seen in one day than anywhere else in the country. And at the Kootenai River, you might see a profusion of bald eagles on a single autumn day.

Montana has yielded some of the world's most significant dinosaur discoveries. The

Biking in the shadow of the Rocky Mountain Front



Donnie Sexton

Montana's open land and majestic mountains make it a rare and special place

fifteen stops along the Montana Dinosaur Trail allow you to discover these paleontological treasures for yourself. Some of the dinosaurs were uncovered at the famous Hell Creek Formation, dating from the late Cretaceous period. This site in the badlands frequently produces finds, including those at the Makoshika Dinosaur Museum: a life-size *Allosaurus*, a *Stegosaurus* in combat, and *Pterosaurs* of all sizes. The first *Tyrannosaurus Rex* ever discovered, back in 1902, was found in Hell Creek near Jordan, which is now home to the Garfield County Museum. Find a dinosaur, or at least a dinosaur tooth, on your own: both the Garfield and the Makoshika, and many other sites along the trail, offer field digs to the public. And, don't miss the life-sized fleshed out model of Peck's *Rex* at the Fort Peck Dam Interpretive Center and Museum.

Within Montana's 147,000 square miles of terrain, there are about 69,000 miles of public highways and roads, making it easy to get around Big Sky Country. Scenic drives such as the Lewis and Clark Trail and the Nez Perce Trail take you among prairies, mountain ranges, and ghost towns, with many glimpses of wildlife along the way. Perhaps the best known of the scenic roads is the Beartooth Highway, which Charles Kuralt deemed "the most beautiful highway in America." Now a Scenic Byway, the Beartooth offers skytop views of snow-capped peaks, glaciers, alpine lakes, and plateaus. The three-hour drive reaches heights of nearly 11,000 feet, transitioning from a lush forest to alpine tundra in the space of a few miles. You'll spot Rocky Mountain goats, moose, black and grizzly bears, marmots, and mule deer along the way.

In Montana, everyone has a few wild neighbors—not the kind who throw all-night parties but antelope, elk, moose, mountain goats, bighorn sheep, eagles, trumpeter swans, bears, wolves, and more. Montana has a greater variety of wildlife than any other state in the lower 48, and some of the best places for



Donnie Sexton



Donnie Sexton

Top: Missouri River,
northeastern Montana
Left: Buffalo roaming
in Yellowstone National
Park

sightings are Yellowstone and Glacier National Parks and the National Bison Range. Also rewarding are Montana's many wildlife refuges, most of which offer self-guided opportunities for photography, wildlife viewing, scenic vistas, primitive camping, hiking, and other year-round outdoor activities. The Charles M. Russell National Wildlife Refuge in Missouri River Country is the third largest refuge in the continental U.S. It's home to elk, mule deer, red foxes, and coyotes, as well as an abundance of songbirds; look for ospreys, spotted sandpipers, and white pelicans along the boundaries of the reservoir.

To help you plan your Montana getaway, order a free travel kit including a 2007 vacation planner, packed with information, travel tips and calendar of events at visitmt.com.



+
PEACE

47:27.95N 112:36.02W

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Sunrise on the Rocky Mountain Front

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+
QUIET



Tumacacori National Historical Park



Copper Queen Mine

Arizona's rich and storied landscape is a treasure for intrepid travelers

IN ARIZONA, GENUINE DISCOVERIES and off-the-beaten-path experiences await around every corner. From vast ranchlands to historic mining towns, from Native American ruins to fossils 225 million years old, this is a destination unchanged by evolution. Here, charming small towns—like Bisbee and Tubac—preserve their heritage and yet carve unique, and often artistic, niches in Arizona's present.

In its heyday the former mining town of Bisbee in southeastern Arizona was the region's mining, commercial, financial, and cultural center. Once known as the "Queen of the Copper Camps," Bisbee retains much of the flavor of yesteryear. Although its mines have closed, visitors still flock to Bisbee's hot spots, including its underground tours of the Queen Mine, the Brewery Gulch, Copper Queen Hotel, and the Lavender Pit.

Tubac, south of Tucson in Arizona's scenic high desert, is the oldest European-settled city in the state, established in 1752 as a Spanish presidio (fort). Artist studios now surround the grounds that once served as the home for a Spanish military garrison.

Explore Tubac's origins at the Tubac Presidio State Historic Park (Arizona's very first state park), located in the Old Town. Nearby, the Tumacacori National Historical Park protects the ruins of three of the oldest Spanish colonial missions in the state.

San Xavier del Bac Mission, noted for its beautiful colonial architecture and colorful interior art, is nine miles south of Tucson. This brilliantly white structure rises from the desert floor of dusty green mesquite and sage; its imposing dome and lofty towers, rounded parapets and graceful spires are a seamless blend of Moorish, Byzantine, and late Mexican Renaissance architecture. It is acclaimed by many as the finest example of mission architecture in the United States.

Arizona's timeless discoveries can be found in every corner of the state. Venture off main roads and get to know the people and the land. The spirit of the legendary Old West continues to thrive throughout the state in small towns, guest ranches, and Native American nations. Bring an adventurous curiosity, leave your watch at home, and simply enjoy. You're in Arizona.



San Xavier del Bac Mission

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ARIZONA
GRAND CANYON STATE

In Tucson, take a walk on the wild side — and the urban side, too



Todd Brenneman

IF YOU'RE PASSIONATE ABOUT HIKING, climbing, or walking, Tucson is your dream come true.

In the beautiful parklands surrounding the city, you'll find a hiker's paradise of trails, ranging from leisurely strolls to challenging treks that can take you from desert floor to pine-topped mountain peaks. Sabino Canyon boasts spectacular views, a variety of wildlife, and dozens of marked trails ranging from easy to rugged, the easiest one that takes you up 3.8 miles up the spectacular canyon.

Saguaro National Park West also has many great trails, including the Sendero Esperanza, which guides you to the top of 4,600-foot Wasson Peak in about two hours. Go north on Catalina Highway to Mt. Lemmon, thousands of feet above Tucson, to enjoy temperature averaging about 20 degrees cooler, and hike the





beautiful 6.5-mile Butterfly Trail.

Also in north Tucson, the Pima Canyon Trail—an exceptional hike for wildlife viewing and dramatic scenery—begins with a steep climb as you enter the canyon, then criss-crosses the streambed, offering a variety of short climbs and descents. Pima Canyon is a bighorn sheep preserve. Its steep climbs and rugged trails are for intermediate and advanced hikers. Finger Rock Trail is a highly visible landmark in the Santa Catalina Mountains—the climb is steep—you'll go from 3,000 to well over 7,000 feet. It's meant for intermediate to advanced hikers—but its rewards include plenty of wild and plant life, and stunning views of the city below.

For a more leisurely pace, take an urban

hike. Follow the turquoise line along the Historic Presidio Downtown Walking Tour/Turquoise Trail, a path that leads to 23 numbered locations; plaques in English and Spanish detail colorful histories. You can pick up the trail anywhere, but we suggest starting at Church Avenue and Washington Street. This is the site of the Presidio San Agustín de Tucson, a fort established in 1775 that marked the northwestern edge of the Spanish frontier in Arizona.

Several splendid short trails run along the dry riverbeds near the city, including the mostly flat Santa Cruz River Park Trail. This route follows the banks of the normally dry Santa Cruz River west of downtown. To get to the trail, simply follow any major downtown street west to the river. The Rillito River Park Trail winds through the city along the north side of the Rillito riverbed. The asphalt trail is a favorite for walkers, joggers, skaters, and cyclists of all ages, and it's designed so you never have to cross any streets.

To start planning your Tucson vacation go to www.visitTucson.org.



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Photos: Alabama Gulf Coast Convention & Visitors Bureau

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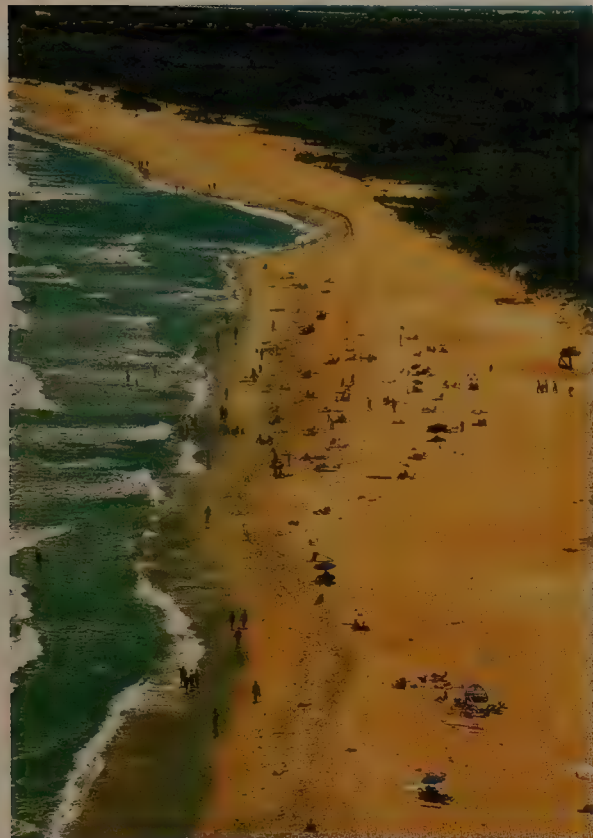
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No Bones About 'Em

The biggest fishes in the ocean may have opted for cartilage over bone to bulk up without getting weighed down.

By Adam Summers ~ Illustrations by Tom Moore

Cartilage, the stuff most people associate with bendable ears and noses—or with career-ending injuries in professional athletes—seems a poor choice of material for the skeletons of the world's most formidable fishes. Nevertheless, sharks, skates, and rays have entirely cartilaginous skeletons—even their jaws are made of the soft material. Such scaffolding must work well, because the group boasts the largest and some of the fastest species of fishes in the sea.

Bone would have been a stronger and, one would think, more useful skeletal building block for sharks. In fact, bone predates them, and it played a role in the skeletons of some ancient, now-extinct sharks. So why did the

ancestors of today's sharks and other cartilaginous fishes abandon bone in favor of a skeletal material that other large animals use only sparingly? I have recently come to think that cartilage gives sharks at least one important selective advantage: they can grow much bigger than bony fishes.

Now anyone who knows a fisherman also knows how hard it can be to pin down the size of fishes. Most people would agree that the gentle, planktivorous whale shark ranks as the largest fish in the sea. Some might even guess that second place goes to another plankton eater, the basking shark. Next in line, the scourge of Amityville, is the great white shark. After that, the ranking

gets more nebulous and more prone to fishing lore. Still, the strongest contenders for numbers four through eight are all cartilaginous fishes: the Greenland shark, the manta ray, the sawfish, the six-gill shark, and the tiger shark (not necessarily in that order!).

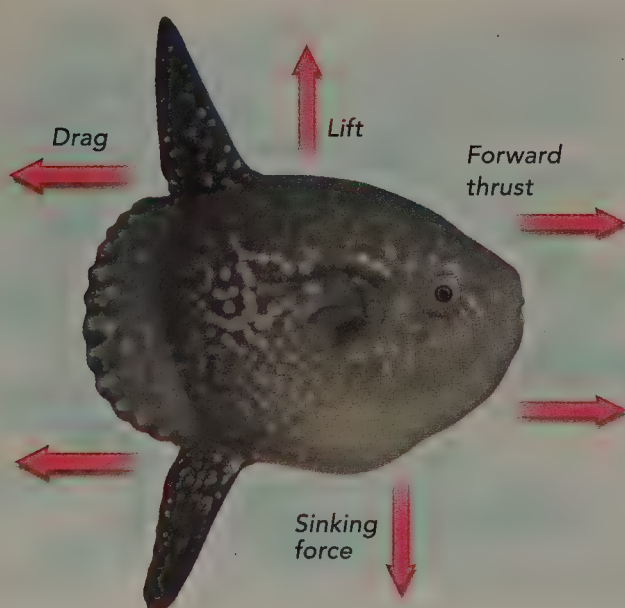
All of them, each classified in a separate family, are larger than the two largest fishes classified as "bony": the beluga sturgeon and the ocean sunfish. And yet the sturgeon, which has reliably

been weighed at just about a metric ton, and the ocean sunfish have skeletons made almost entirely of cartilage. The marlin takes the prize for being the largest bony fish that actually has a skeleton made entirely of bone, but its weight is less than 80 percent that of the sturgeon's.

Patricia Hernandez of George Washington University in Washington, D.C., James A. Strother at the University of California, Irvine, and I have constructed a model that attempts to explain why cartilage became the skeletal material of choice for the giant fishes of the ocean. Picture a fish swimming at a constant speed. The swimming muscles generate thrust that exactly offsets the drag of the body as it moves through the water. (If the offset were inexact, the fish would speed up or slow down until a new constant speed was reached.) Similarly, as long as the fish moves forward, the fins and body generate lift that exactly counteracts the fish's tendency to sink [see illustration on this page]. That sinking tendency is known as negative buoyancy, and all fishes (and overweighted scuba divers) have it—all fishes, that is, except dead ones, which tend to float. Yet most fish tissues, from muscle to guts to nerves, are almost neutrally buoyant. Not so the skeleton, which is largely responsible for that slight sinking tendency.

So consider what would happen to the fish's physical dimensions if, magically, it doubled in size. Three aspects come to mind: length, area (the shadow cast by a light shining from above), and weight. Double the fish's length, and, presumably, the animal also doubles in width. The new fish has not twice its former area, but four times as much. As for weight, it is tied to volume, which is equal to the length times the width times the "height." When length and, presumably, width and height are doubled, weight goes up eightfold.

So what would happen to the nega-



Ocean sunfish swimming level at a constant speed is subject to four forces—drag, forward thrust, lift, and sinking force (or "negative buoyancy")—that are paired, each pair in perfect balance. If a fish were to grow too large, the sinking force would overtake lift.



The world's largest fishes, as seen from the perspective of a snorkeler looking down, all have enormous profiles. Each profile and the lift generated by each of the creatures' forward swimming motion would grow fourfold if the creatures doubled in size, but their volumes (see inset above) and their weights would grow eightfold. Because lift grows more slowly than weight, the biggest fishes conserve weight with skeletons made of cartilage, not bone.

tive buoyancy of a fish as it increases its length? Well, the weight of the skeleton should directly correlate with the weight of the fish, so the skeleton's negative buoyancy should cube when length is doubled. But the lift force needed to counteract the negative buoyancy scales quite differently. The key to lift is the "profile" of the lifting surface—another way of describing the shadow cast by the fish. Lift, therefore, should grow with the square of the length rather than the cube.

That sets up a fundamental problem. Because lift grows more slowly than the negative buoyancy acting against it, a growing fish species even-

tually runs out of lift; thereafter, it would be doomed to a life of squirming along the bottom. Of course, cartilaginous and bony fishes are in the same bind, but the cartilaginous skeleton weighs considerably less per foot of fish than the bony one. The propensity to sink kicks in at a longer length and a greater weight. It seems that one advantage of the cartilaginous skeleton is something of a reprieve from a size limit [see illustration above].

The skeptical reader is no doubt wondering how whales—not to mention extinct animals such as the plesiosaurs and Steller's sea

cow—avoided the sinking trap. Those animals are (or were) all larger than the largest bony fish; in fact, the blue whale is the largest animal on the planet. But they have one thing in common: they all come from lineages that have returned to the sea after an evolutionary stint on land. They no longer swim as fishes, gliding through the middle depths in dynamic equilibrium. Instead, their lungs act as flotation devices, and they remain tied to the surface by positive buoyancy, which, to descend, they must swim against.

The motto of the early sharks that wanted to get bigger was not "bone stinks" but rather "bone sinks."

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Bad News for Bears



For thirty years the wild Alaskan bears that visit McNeil sanctuary have learned to trust the people who watch them. But this fall, despite a public outcry, those bears may be hunted.

By Bill Sherwonit

On a bright August morning, with gulls screeching and bald eagles picking at spawned-out salmon, I'm standing with ten other people in the shadows of an alder-topped bluff. Our backs are pressed tightly against a dank rock wall. Everyone's attention is drawn to the left, where the bluff ends abruptly in a blind corner.

Douglas D. Hill, who's guiding our group, had peeked around that corner only moments earlier, then ordered the rest of us to stand quietly against the wall and remain absolutely still. Several more moments pass. Now, hardly daring to breathe, we watch as an adult brown bear rounds the corner,

as if in slow motion, and angles our way. Passing within less than twenty feet of our party, the 600-pound animal scarcely acknowledges our presence as she squishes through mud and wades into the stream that flows before us.

That in itself is enough to send adrenal glands into overdrive. Imagine the tension, then, when two small cubs step gingerly into view and turn our way. Unlike their mom, the cubs eye us intently and pick up their pace, clearly anxious. But not so anxious that they run or cry or give us a wide berth. Barely larger than the teddy bears awarded as carnival prizes, the dark-chocolate spring cubs scoot



Dozens of brown bears come to McNeil Falls in southern Alaska from June until August during the annual chum-salmon run. A strict limit is imposed on the number of visitors allowed into the area: ten per four-day period. They watch from two gravel pads a hundred feet away. The bears treat their audience as part of the scenery, focusing instead on each other and on catching fish.



past our wall-pinned bodies, no more than ten feet away. Several yards beyond us the cubs wrestle with each other, perhaps a release of tension. Then they lope toward their mother, intently hunting salmon in the swirling, muddied water.

Anyone passionate about brown bears will instantly guess where our encounter took place. It can only be McNeil River State Game Sanctuary, a 200-square-mile parcel of coastland situated on the upper Alaska Peninsula, some 250 miles southwest of Anchorage. McNeil is the standard against which all other bear-viewing sites are measured. Established in 1967 and managed by the Alaska Department of

Fish and Game, the sanctuary protects the world's largest gathering of brown bears—the coastal cousins of the grizzlies. As many as a hundred bears come to McNeil River Falls every summer to feed on chum salmon. It's not uncommon for visitors to see dozens of brown bears at a time congregating by the falls.

The McNeil bears are now threatened. The Alaska Board of Game, which has jurisdiction over McNeil and several surrounding areas, has voted to allow hunting in the Kamishak Special Use Area, adjacent to McNeil to the east and south [see map above]. Both before and after the salmon return to McNeil River, the bears fan out throughout the

region, often far beyond the McNeil sanctuary. Tagging and radio-collar studies in this area have shown that some bears travel hundreds of miles in a year and that many McNeil bears venture into the Kamishak Special Use Area. So if open hunting there remains legal, it is only a matter of time before trophy seekers kill some of McNeil's most tolerant and approachable bears.

Protecting the McNeil bears is the stated mission of the Alaska Department of Fish and Game, which is why it established a permit system to keep human visitors at the site to a minimum. A state-run lottery attracts as many as 1,400 applicants, but permits are granted to just ten people at a time for consecutive four-day periods from early June through late August. Visitors take their seats on folding chairs placed side by side on two gravel pads within a hundred feet of the falls. The bears eat, nap, nurse, or even mate not far from the pads where the viewers sit transfixed by the action for as long as eight hours a day.

Many people are surprised by the bears' neutral attitude toward their fans. "Think about it," says Larry Aumiller, McNeil's former manager. "You've got this group of people standing in the middle of dozens of bears. You're very close to where they want to be. And they tolerate you."

Before the McNeil "experiment," many bear experts thought that habituated bears, particularly

browns and grizzlies, were extremely dangerous because they had lost their natural shyness of humans. But Aumiller showed that habituated bears that have not learned to associate humans with food treat people as "neutral objects, maybe as innocuous as rocks or trees." Still, habituated bears remain wild; they should not be confused with tamed animals. As Werner Herzog's widely released documentary film about Timothy Treadwell, *Grizzly Man*, made clear to a worldwide audience, carelessly approaching any bear in the wild can have fatal consequences.

Because of the precautions that Aumiller and his staff have taken, no McNeil bears have attacked or injured anyone in more than three decades of close association with people.

And no bears have had to be killed because they presented a danger. Those facts demonstrate that these bears are safe to be around if people are willing to adjust their behavior. "What goes on here is still news to a lot of people," Aumiller says. "They don't think it can happen. But it does. McNeil shows that if you learn about something that's different from you, and begin to appreciate it, then you'll figure out a way to keep it in your life. You'll learn to peacefully coexist."

When he first came to McNeil, Aumiller didn't think he'd stay more than a season or two. But two years became three, then five, and he found himself in love with both the landscape and its ursine residents. Here was a place he could stay forever.

By the mid-1980s, the "Bear Man of McNeil" was something of a local legend. And by the early 1990s, he had become widely recognized as one of the world's leading authorities on brown bears. Aumiller himself always pooh-poohed such acclaim. He humbly insisted (while adapting another cliché) that the more he learned about bears, the more he realized just how little he knew.

Yet as two decades at McNeil turned into three, Aumiller was beginning to contemplate what he once imagined impossible: resigning his position. Married, with a young daughter, he found it harder to spend his summers in the wilderness. An even bigger issue, though, was wildlife politics.

In 2002 Frank H. Murkowski, a Republican, was elected governor of Alaska, bringing new threats to McNeil's bears and heartache to Aumiller. No friend of bears and wolves, the governor was strongly endorsed by the Alaska Outdoor Council, a self-styled "sportsmen's group." AOC's leaders are strong advocates of hunters' rights and predator control, and for years the group has pushed for increased opportunities for bear hunting on state lands near McNeil. By the time of the spring 2005 meeting of the Alaska Board of Game (BOG), Murkowski had appointed enough AOC allies to it to make that wish come true. The BOG, which reports to the governor, determines whether hunting is allowed on federal, state, and private lands.

At the same time, McNeil's bears were receiving a huge outpouring of public support, expressed by thousands of written comments, as well as in public testimony of dozens of Alaska residents, including many hunters. Yet despite the outcry, and despite a substantial drop in the population of McNeil's bears since the late 1990s, the board voted to approve a new bear hunt in the Kamishak. (The details of the hunt, scheduled for fall 2007 and spring 2008, have yet to be worked out.) The population decline was



Larry Aumiller, pictured here in a photograph taken in 1988, never once had to use his shotgun in his thirty-year tenure as the manager of the McNeil sanctuary. If a curious adolescent bear got too close to a visitor, Aumiller would clap loudly until the bear moved away.

most likely caused by diminished salmon returns and by increased brown bear hunting in Katmai National Preserve, another tract bordering McNeil, which is managed by the federal government. In fact, the number of bears legally killed in the areas surrounding McNeil has jumped to forty-five in 2005, more than double the number in the early 1980s.

Disheartened by the BOG's actions, Aumiller chose to leave his beloved job after the 2005 season, his thirtieth at McNeil. In an opinion piece for the *Anchorage Daily News*, he explained his action:

More than any other single person, I am responsible for habituating McNeil bears to humans. That means that through every single interaction for over 30 years, we have done everything humanly possible to get bears to accept our benign presence. And guess what? It has worked incredibly well. . . . Because we have cultivated their confidence, we have more responsibility to protect them. The very bears that trust us the most are the most vulnerable to hunting, which will be occurring literally a one-hour walk away from McNeil Falls.

To purposely and knowingly kill these habituated animals for trophies is beyond any definition of reasonable ethics or fair chase and, I believe, is morally wrong. I've always envisioned that I'd be at McNeil River until I couldn't physically do it anymore. But I can't continue to remove the bears' only protection—their natural wariness—knowing that even more of them will soon be exposed to hunting.

Doug Hill, Aumiller's replacement, has worked around bears before, but he is completely new to McNeil. Furthermore, many people who visited McNeil in 2006 already knew about the hunting debate. Many visitors wanted to know what they could do to protest the BOG's actions and ensure the protection of the bears.

"It's gotten to the point where I don't want to talk about it anymore. I've tried to stay clear of the politics," Hill admits. "At the same time, it's our job to protect the bears. It doesn't make sense that we'd be neutral about hunting near McNeil."

One staff member, Thomas M. Griffin, says his approach is "to tell people, 'It's up to you to decide what's right or wrong.'" Away from visitors, Griffin is less hesitant to share his opinions. "Are we setting these animals up? Oh yeah. It's a no-brainer. Where's the sport in hunting habituated bears? Where's the fair-chase ethic?"

In recent years, the BOG and other hunting advocates have consistently argued that hunting and killing a few bears won't harm either the McNeil

experience or threaten the sanctuary's gathering. Ronald J. Somerville, a member of the BOG and one of the chief proponents for increased bear hunting near McNeil sanctuary, advanced that argument at the 2005 meeting that approved the Kamishak hunt set for 2007. "There is no mutually exclusive conflict between viewing bears and hunting them," he said then.

In fact, however, Somerville also suggested making hunting legal in McNeil River State Game Refuge, a 188-square-mile block of land just north of the sanctuary, where bears were afforded additional protections beginning in 1993. All bear hunting has been prohibited in the refuge since 1995. But the board agreed at the spring 2005 meeting that Somerville's proposal to allow hunting in McNeil refuge would be on the BOG agenda for



Visitors to McNeil sanctuary can watch for as long as eight hours a day, from chairs set up on the two viewing pads. The bears nap, nurse, and even mate as close as twenty feet from their human audience.

its meetings this month from the 2nd through the 12th. In spite of the agenda vote, the board did not file Somerville's proposal by the required deadline. But the board could still bring the McNeil refuge into the discussion of the scheduled hunt in the Kamishak Special Use Area, which is formally on the agenda. Somerville, appointed chairman of the BOG in 2006, did not respond to repeated requests by *Natural History* for comment.

Ted H. Spraker, another board member and a former state wildlife biologist, says that the compatibility of viewing with hunting was not uppermost in the minds of board members when they approved the Kamishak hunt: "People need to understand that we weren't targeting McNeil's bears when we

reviewed the Kamishak area's bear-hunting closure. It was simply part of a long-overdue review of hunting closures statewide."

The reasons for approving the Kamishak hunt were largely political, Spraker adds, a tactical response to a long-standing dispute between the state and the National Park Service (NPS) over lands—including the Kamishak Special Use Area—that the two parties agreed to trade years ago. Spraker and other board members argue that the NPS reneged on the deal once the Kamishak area was closed to hunting, a charge the NPS denies. By reopening Kamishak to bear hunting, Spraker says, board members hoped they would force the NPS back to the negotiating table.

"The board had good intentions, but it looks like [its tactic] may backfire on us," Spraker admits. "We puffed up our chests, played our cards. Now we may have to fall on our swords."

"We still could postpone any hunt [at the board's meeting this month]. I can't speak for the entire board, but I'd push for a delay in the hunt, and give the park service more time to deal with us."

Benjamin F. Grussendorf, a former state legislator and one of two board members to oppose the new hunt, refuses to speculate on the motives of the five who approved it. But Grussendorf has no doubt that "it was an unnecessary thing to do, to rile people up and create a huge public outcry, simply to allow for two or three more bears to be harvested. It just isn't worth it."

But like Spraker, Grussendorf suspects the BOG will "take a second look" at the Kamishak hunt during its March meeting. "I think you'll have some board members looking at things differently."

Whether he's had a sudden change of heart or not is hard to say, but Spraker now essentially agrees with Aumiller: "To be honest, I would hate to see [the Kamishak area or McNeil refuge] opened; I'd like to see a continuous area protected." To approve a hunt, he adds, "would cost both the board and hunters a lot of credibility. I don't think the opportunity to take a few more bears is worth the black eye it would give to either hunters or the state."

Spraker was the only board member who voted

to open the Kamishak area to hunting who could be reached for comment.

In November 2006, voters elected a new Republican governor who is an avowed advocate of hunting. Sarah Palin, like her predecessor, was strongly endorsed by the AOC when she ran for governor, and is a member of the organization, which in recent years has largely gotten its way.

When asked about the bear-hunting controversy, Palin's deputy press secretary, Charles Fedullo,

responded this way via e-mail:

"The governor said she is a hunter and that . . . some of her best memories growing up are of hunting with her dad to help fill the family freezer. She wants Alaskans to have access to wildlife [to hunt]. However," he added, "she does not support bear hunting in the McNeil River State Game Sanctuary."

Beyond that, including on the issue of increased hunting around the sanctuary, Palin was more evasive. "The governor wants to wait till she, along with the fisheries and game boards, names a Fish and Game Commissioner to delve further into the issue," said her spokesman.

Palin knows she must tread lightly. She is surely as aware as the members of the BOG that any attempt to open McNeil refuge even to a limited hunt (as it was in fall 1995 and spring 1996) is likely to meet with intense and widespread opposition—even

among many hunters and big-game guides. Those 1995 and 1996 hunts inspired hundreds of hunting opponents to swamp the real hunters by applying for the eight available permits; largely because of that protest effort, only one bear was killed.

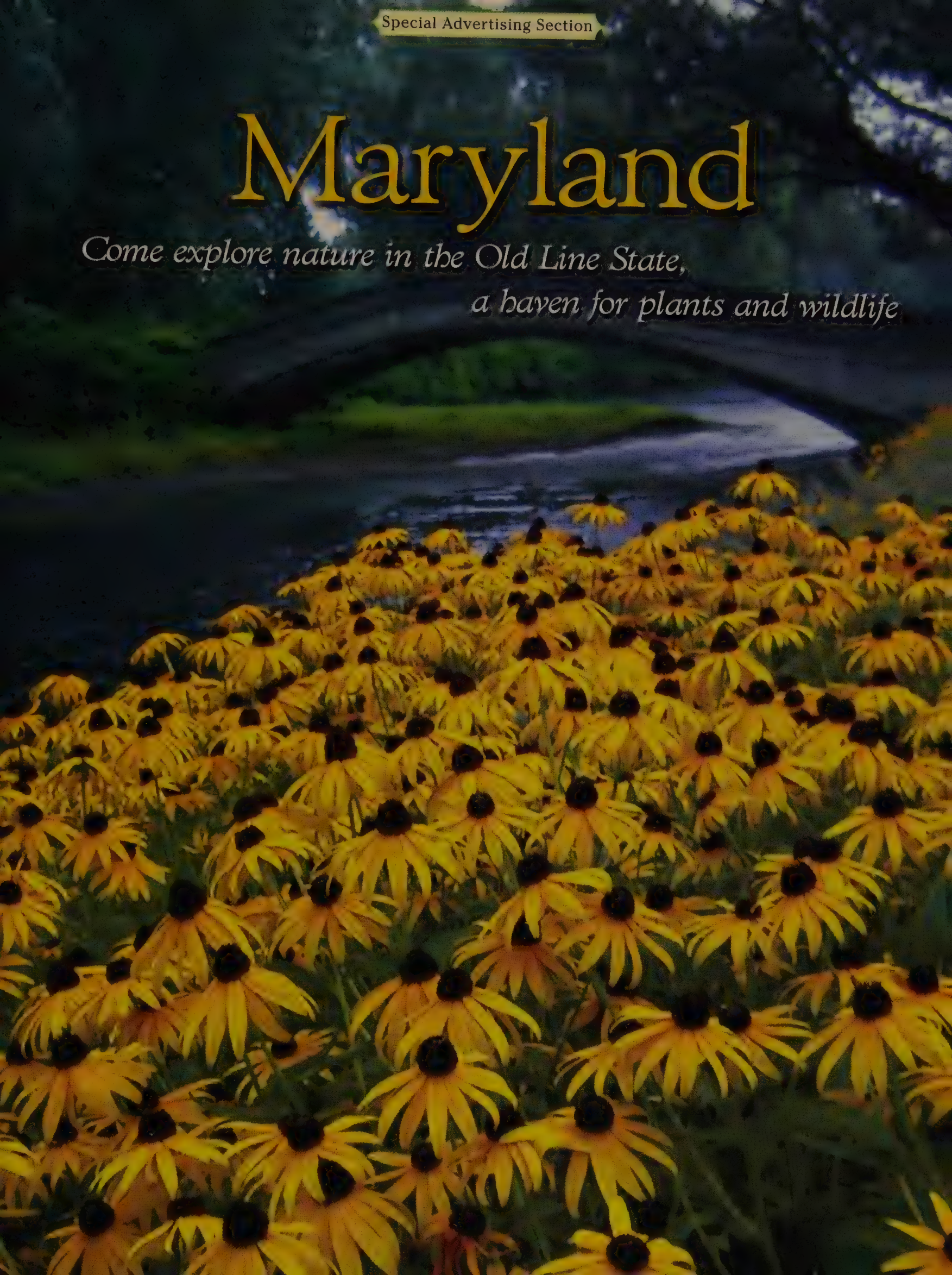
But neither she nor the BOG can continue to dodge the looming question for long: Will the BOG again ignore overwhelming public sentiment and follow a path that, as Aumiller puts it, introduces new risks to the world's most famous and successful brown-bear sanctuary? Or, as Spraker has suggested, will it adopt a more moderate course: admit that opening the lands adjoining McNeil to hunting is a big mistake and make it clear that in McNeil, perhaps more than anywhere else in the world, the bears do indeed come first? □



Hunters killed forty-five bears in 2005 in the areas surrounding McNeil sanctuary. The decision to open a new area to hunting adjacent to McNeil may lead to the killing of some of McNeil's most approachable, human-tolerant bears.

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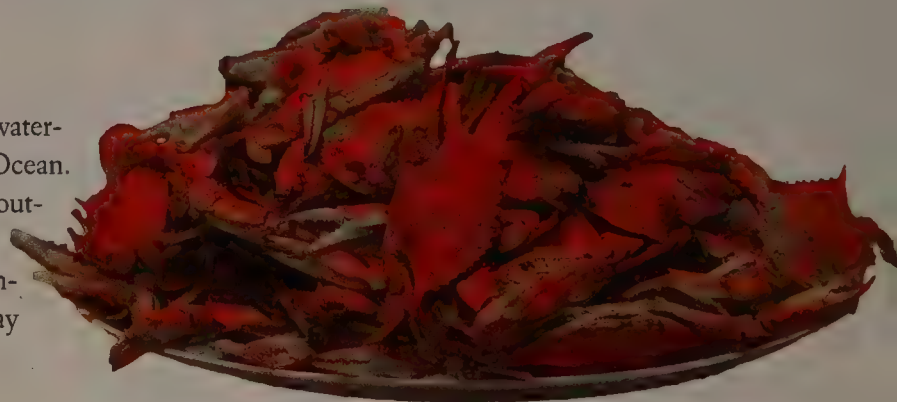
“America in Miniature,” as *National Geographic* once called the state, Maryland boasts mountains, seashores, cities, countryside, and everything in between—all within a three-hour drive of Baltimore.

In **Western Maryland**, the Allegheny Mountains serve as the stunning backdrop to rolling countryside, fast-moving rivers, and scenic Deep Creek Lake, the centerpiece of Western Maryland’s resort area. With 65 miles of shoreline and covering nearly 3,900 acres, the lake is perfect for boating, swimming, and fishing. At Wisp, a year-round resort, learn to fly-fish, kayak, or golf. The mountains, as well as scores of forests and parks, offer well-marked hiking trails through undeveloped, scenic settings. History buffs should seek out such sites as the C&O Canal and Antietam National Battlefield.



Central Maryland is home to the state’s capital, Annapolis, and to its most vibrant city, Baltimore. But the region also offers the pleasures of the Chesapeake Bay shoreline, serene wilderness, and charming small towns. Baltimore, a natural deep-water port that has been attracting ships since the 1600s, is today a modern seaport. Maritime history is everywhere but best seen around the city’s Waterfront Peninsula. In addition to its celebrated Inner Harbor, Baltimore has fascinating neighborhoods, intriguing museums, and a wealth of restaurants where you can try out Maryland’s famous blue crabs and fresh seafood. Annapolis—America’s sailing capital—is celebrating its 400th anniversary in 2007. Since it became the state’s capital in 1695, much of Annapolis has remained intact, with more surviving colonial buildings than any other place in the country.

In 1634, the first European settlers arrived in what is now known as **Southern Maryland**. Here you’ll find unique communities of watermen and farmers living between the Chesapeake Bay and the Atlantic Ocean. The state’s original capital, Historic St. Mary’s City, is preserved as an outdoor, living history museum on the banks of the St. Mary’s River. In addition to quaint waterside towns, you’ll find some of the best bass fishing on the East Coast, and boating opportunities on the Chesapeake Bay and the Patuxent and Potomac rivers.



Known as the **Capital Region**, the three Maryland counties that border Washington, D.C. offer convenient, hassle-free access to D.C.’s museums and monuments. But there are plenty of reasons to stay on the Maryland side of the border: a plethora of historical sites, state and national parks, and an array of restaurants, theaters, and cultural attractions. Perhaps unexpectedly, the area also attracts wildlife—species found here include deer, wild turkey, various reptiles and amphibians, and birds. It boasts the largest concentration of Canada geese on the Chesapeake Bay’s western shore.

The **Eastern Shore** is known as “the Land of Pleasant Living” because of its quieter pace. During the day, you may run into a farmer or waterman bringing produce or fish to the restaurant where you’ll be dining at night. You’ll find immaculately preserved waterfronts and a maritime tradition unique to the area. Explore the majestic lighthouses that dot the seashore and have shown the way to centuries of seafarers—postcard-pretty reminders of the state’s maritime heritage. The Eastern Shore also has superb national wildlife refuges—Blackwater and Eastern Neck—featuring major nesting populations of bald eagles, flocks of migrating waterfowl, and hundreds of other bird species.

With such a wealth of diversity in geography, attractions, and wildlife, Maryland makes it easy to plan an unforgettable getaway. Read on to learn more about the state’s travel opportunities.



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In summer 2007, a crew of explorers, historians, naturalists, and educators will reenact Captain John Smith's 1608 expedition. Traveling in a 28-foot reproduction of Smith's shallop, and living much as Smith and his men did 400 years ago, the crew will voyage to almost every tributary of the Chesapeake Bay. Calvert County will host two stops. On June 9-10, the shallop will stop at the Calvert Marine Museum in Solomons to commemorate Smith's exploration of the Patuxent River and his encounter with the Patuxent Indians. On Sunday, August 5, the shallop will arrive at Jefferson Patterson Park and Museum to participate in its annual American Indian Heritage Day. The day will feature a recreated Indian village, dancers and drummers, traditional arts, and skilled demonstrations of flint-knapping, basketry, and pottery and fire making. Come learn about this important episode in the history of the Chesapeake.



Rich in history and tradition,
Carroll County is a haven
for Civil War buffs

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Carroll County has so many things to do and see. Walk or drive along the scenic roads where Civil War troops trekked and camped on their fateful march to the Battle of Gettysburg. Learn about life on a 19th-century farm at the Carroll County Farm Museum, or explore the great outdoors at the Piney Run and Bear Branch Nature Centers. With an old-fashioned swimming lake, as well as parks for fishing and hiking, it's easy to get close to nature. The county also boasts an operating grist mill, quaint Main Streets lined with art galleries and antiques shops, a small family winery, and local theater. For a free information packet to help you plan your trip to the county, call 1-800-272-1933 or visit carrollcountytourism.org.

Charles County claims the wildest wildlife this side of the Potomac

Located twenty miles south of Washington, D.C., Charles County is the gateway to historic Southern Maryland. It has first-class fishing (in both the Potomac and Patuxent rivers), an abundance of undeveloped forests, 150 miles of spectacular Potomac shoreline, sumptuous fresh seafood, and top-flight golf. Purse State Park, a reserve of gently rolling hills, woods, and marshlands, is the perfect site for fossil hunting. The county is a haven for birds, with 231 bird species and the second largest bald eagle population in Maryland. It also has enough history to fill several books. Tour the Dr. Samuel A. Mudd House Museum, the home of the country doctor who set the broken leg of President Lincoln's assassin. Explore the numerous historic churches, some among the oldest in the nation.



Come see eagles soar at Blackwater National Wildlife Refuge in Dorchester County

Plan an Eastern Shore getaway with a trip to Dorchester County in the Heart of Chesapeake Country. Boasting 1,700 miles of shoreline, this unspoiled countryside offers many opportunities to enjoy nature. A major stop on the Atlantic Flyway, Blackwater National Wildlife Refuge has more than 27,000 acres of significant wetlands and woodlands with

hiking, biking and paddling trails. The refuge boasts more than 250 bird species, including the largest nesting population of bald eagles north of the Florida Everglades, and huge flocks of ducks, geese, and swans in the peak migratory periods. The newly updated visitor center offers exhibits, an observatory, a butterfly garden, and an enlarged gift shop.

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Scenic Frederick County is home to many Civil War sites, rolling farmland, and covered bridges

Less than an hour away from Washington, D.C., Frederick County has a wealth of Civil War history and heritage. You'll find the Monocacy National Battlefield, site of an 1864 battle that played a pivotal role in defending Washington, D.C., and the South Mountain Battlefield State Park (includes Gathland State Park and Washington Monument State Park, where you can hike on the Appalachian Trail).

The Barbara Fritchie House and Museum is a replica of the house where 96-year-old Barbara Fritchie confronted General Stonewall Jackson when Confederate forces marched into Frederick in early September 1862. The National Museum of Civil War Medicine, located in the heart of Frederick's fifty-block historic district, dating from 1745, is dedicated to patients,

caregivers, and medical innovations during the war; soldiers were embalmed in the very same building that now houses the museum.

Frederick is also home to the National Shrine of St. Elizabeth Ann Seton, in Emmitsburg, honoring the first American-born canonized saint, and is the birthplace of Francis Scott Key. But even if you're not a history buff, this scenic county nestled in the Appalachian Mountains and Piedmont Plateau is well worth a visit. Frederick has more farms than any other county in Maryland, and is dotted with vineyards, covered bridges, and old railroads. The town of New Market is "The Antiques Capital of Maryland," and you'll find the largest water garden in the U.S., the Lilypons, in Buckeystown.

Frederick
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The County of Kent, Maryland's Upper Eastern Shore

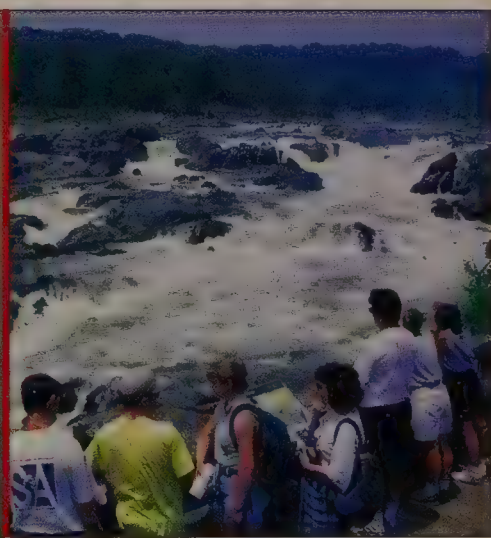
Situated on a scenic peninsula where the Chester and Sassafras rivers meander into the Chesapeake Bay, the County of Kent has retained its serene beauty. Maryland's smallest county claims a coastline sprinkled with historic waterfront towns and stretches of low, rolling farmlands broken only by the tidewater tributaries of the Chesapeake. This quintessentially rural area also is home to a profusion of aquatic birds including ducks, geese, kingfishers, herons, ospreys, and other creatures that make their homes along the reeds and rushes, as well as bald eagles. Eastern Neck National Wildlife Refuge is a haven for waterfowl, wildlife, and fish and offers seven walking trails, many with observation decks. Rock Hall, a small fishing village, is celebrating its 300th birthday this year, with special events throughout the year. Other historic towns of the County are Chestertown, Galena, Betterton, and Millington.

Base your visit to the Capital Region in nearby Montgomery County, with fascinating attractions of its own

Bordering Washington, D.C., Montgomery County is a quick shuttle ride from the airport or Union Station. Visit the Chesapeake & Ohio Canal National Historical Park in Potomac and see an original lock house. Hike or bike on the 185-mile tow path, or take in the spectacular view of the Great Falls of the Potomac River from the Olmstead Bridges. Boyds Negro School House, open by appointment only (301-972-0484), is a restored one-room schoolhouse dating from 1896 to 1936. Glen Echo Park offers year-round dance and theater performances; near Glen Echo, take a free tour of the Clara Barton National Historic Site, home to the founder of the American Red Cross and headquarters of the organization from 1897 to 1904. At the 1,300-acre Black Hill Regional Park, in the northern part of the

county near Germantown, follow the trail to Little Seneca Lake, a popular bird breeding area, or meander through oak and hickory forests. Historical markers along the trails identify a former mill site and recount the area's gold-mining history. Spring blooms are showcased at the county's public gardens including the Brighton Azalea Gardens, with more than 20,000 varieties of azaleas; the fifty-acre Brookside Gardens and its conservatory; and the McCrillis Gardens, featuring azaleas and rhododendrons. Also in the northern area of the county you can take a driving tour to see sites that showcase historical landscapes, recreational opportunities, and the agricultural heritage of the County. Visit www.heritagemontgomery.org for information.

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St. Mary's County—Maryland's oldest—invites visitors to relax on the serene Chesapeake shore



Shaped by the Chesapeake Bay and its tributaries, the Patuxent and Potomac rivers, St. Mary's is Maryland's oldest county, settled in 1634. The first battle of the Revolutionary War occurred on low-lying St. George's Island. Now a quiet fishing community, the island is home to the Chesapeake Bay Field Lab, where you may cruise the Bay aboard the authentic skipjack *St. Mary's Dee*. Once an oyster packing plant, the Lab runs a shore-side

program for visitors who want to learn to tie a bowline, tong an oyster, or test the water. Nearby Piney Point features the first lighthouse on the Potomac, which began operating in 1836. Exhibits at the

Piney Point Lighthouse Museum include several historic wooden vessels that once sailed the Bay. This area of beach grass and tall pines has a campground and several marinas. Nearby attractions include Historic St. Mary's City, on the site of the state's original colonial capital, and is one of the nation's premier archaeological parks and living history museums, as well as Point Lookout State Park, which has fishing piers and campgrounds.



Talbot County's uniqueness belongs to its quaint towns and their treasury of history, heritage, culture, and architecture

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Talbot County

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www.tourtalbot.org

Talbot County Office of Tourism
11 S. Harrison St., Easton, MD 21601

Escape to Talbot County and explore historic Colonial towns and Chesapeake Bay watermen communities accented with the traditions of the Eastern Shore. Bustling with art galleries and antiques, Easton is rated among the Top Ten Best Small Towns in America and one of the Top 100 Small Arts Communities in America. Oxford was featured in James Michener's *Chesapeake*, and St. Michaels is the picture-perfect historic waterfront town. Unionville is a historic African-American community settled by former slaves and free blacks, many in the Union Army during the Civil War. And Wye Mills is one of the oldest towns in Maryland, filled with such historic gems as the Old Wye Grist Mill and Museum, the Wye Church, and the Little Red Schoolhouse, just fifteen miles from the Bay Bridge.

Your Chesapeake Bay experience begins here

Situated on eighteen waterfront acres in the historic town of St. Michaels, the Chesapeake Bay Maritime Museum tells the story of the Bay and the people who have shaped their lives around it. Explore ten exhibit buildings, the world's largest collection of traditional Bay boats, and the 1879 Hooper Strait Lighthouse.

Rediscover the fun of playing on the Bay, learn about the heritage of oystering and waterfowling, and get a new perspective on the Chesapeake through a schedule of changing exhibits. You can get your hands dirty pulling up a crab pot or nipping for oysters on Waterman's Wharf or trying your hand at building a wooden boat in their working Boat Shop, where you may talk with the shipwrights, apprentices, or a visiting captain or boat builder.



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Worcester County is Maryland's prime destination for birdwatching

Located on the Eastern Shore, Worcester County is Maryland's only seaside county, known for Ocean City's sandy beaches, steamed crabs, and the famous wild pony herd on Assateague Island State Park and National Seashore. Worcester also has more than a dozen championship golf courses—enjoyable practically year-round thanks to the mild temperatures near the shore—and a hundred miles of marked bicycle trails on flat country roads. Explore history, architecture, and an easier pace of life in the Victorian-era town of Berlin, with its bed-and-breakfasts, or in Snow Hill, with its more than one hundred century-old homes and proximity to the Pocomoke River. Birders know Worcester as the county with the best birding in the state: almost 300 species have been identified in the county's diverse habitats of

barrier islands, coastal bays, tidal wetlands, cypress swamps, upland fields, and primeval forests. Come spring, Worcester's birds are busy nesting, and northern migrants flock to the county's large unbroken tracts of woodlands. The county has extraordinary fishing in the tidal banks of the Pocomoke River and the Atlantic Ocean. Ocean City is the White Marlin Capital of the World and offers both bottom fishing in the inlets and deep-sea fishing offshore.



Worcester County

MARYLAND

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Lower
Eastern
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Free Bird
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MARYLAND

Bar Coding for Botany

A system modeled on commercial bar codes may soon enable anyone to identify any plant from a small fragment of its DNA.

By Kenneth M. Cameron

What the heck are these? The documents for this crate say the contents are *Polypodium* ferns. Those are perfectly legal to import, but all the leaves have been hacked off these plants. I can't identify them from the stems alone. Jim, can you get a reading on them?"

"Sure—just a second. . . . Well, according to my Global Flora Scanner, they're actually *Stangeria eriopus*, the Natal grass cycad,

which looks a lot like a fern. It's an endangered species from Mozambique—says here they're just about extinct in the wild. They're illegal to import, but collectors are just crazy about them. Apparently some cycads sell for as much as \$20,000 on the black market. I've never intercepted *Stangerias* here at the



airport before. Good thing you spotted them—and that they were in the GFS database. We'd better investigate; this should mean a big fine or even an arrest for the importer."

The dialogue might sound like science fiction, but that kind of scenario could transpire sooner than you think. One of the great biological projects of our time will be to collect DNA sequences from every living species on Earth. The objective is to create a universal genetic database of life. Once it is mostly complete—perhaps a decade from now—the project will enable any plant, animal, fungus, or other organism to be identified simply by sampling its DNA and comparing that with the database of known DNA sequences.

That comprehensive approach to identifying species is called DNA bar coding. As the name implies, the idea is to develop, as explicitly as possible, the analogy with the universal product codes, or bar-code labels, that are attached to nearly every consumer product, from applesauce to zucchini bread. What makes the analogy such a good one? Just as varying the order of thin and thick black

lines in the bar code of a product can distinguish one brand of cough syrup from another at the checkout counter, so the varying order of the four kinds of

nucleotides that make up any fragment of DNA can make it possible to distinguish a bluebird from a blackbird, or a de-leafed *Polypodium* fern from a *Stangeria* cycad. Furthermore, a

number of technological advances in DNA sequencing are on the horizon, making it conceivable that handheld bar-code readers—like my fictional Global Flora Scanner—will become available in our lifetimes. Such a device would extend to customs officials, scientists, and even members of the general public a skill that has long been reserved for specialized taxonomists.

DNA bar coding is the newest of several techniques that promise to make important contributions to the basic science of systematic biology. The discipline seeks to identify and classify organisms, reconstruct their evolutionary history, and map the extent of biologi-

cal diversity—in other words, to build the family tree of life. The use of molecular tools in pursuing those goals has already transformed the way biologists understand the natural world. In particular, the wide availability of DNA bar coding in the future could enable specialists to make rapid, reliable identifications in the field, and make it possible for armies of amateur naturalists to contribute to the study of the range and diversity of species. Within botanical circles, the influence of molecular data on systematics has been revolutionizing the study of plants in the laboratory and in the field.

Since plant systematists first began comparing gene sequences in the 1980s, their studies, more often than not, have simply confirmed classifications that botanists have accepted for centuries. For example, molecular evidence confirms that almonds, apples, cherries, pears, and strawberries are all closely related; all of them are best classified with roses in a plant family called the Rosaceae.

But nearly every study in molecular systematics has also led to its share of surprises. More than ten years ago, DNA data showed that, contrary to the accepted thinking of the day, a number of carnivorous plants that employ radically different methods of capturing animals share a common ancestor. A molecular phylogenetic tree showed that Old World pitcher plants of the genus *Nepenthes* [see "Life and Death in a Pitcher," by Jonathan Moran, October 2006] are closely related to sundews (*Drosera*) and to Venus flytraps (*Dionaea muscipula*), even though the three plants evolved three distinct ways of catching prey: fluid-filled pitfall traps, sticky flypaper traps, and rapidly closing snap traps.

More recently, my collaborators and I demonstrated that *Aldrovanda vesiculosa*, the carnivorous waterwheel plant, is also a member of that highly

Botanists are on the verge of pinpointing a segment of DNA common to all plants, but distinctive for each species, that would make it possible to identify any plant by matching a small sample of its genetic material against a database of known DNA sequences.

unusual group. Like the Venus flytrap, *Aldrovanda* catches its dinner in snap traps. But unlike all other members of the group, it is aquatic. As if that finding were not strange enough, our studies also showed that the same carnivorous-plant group is related to buckwheat, cactus, carnation, jojoba, rhubarb, and salt cedar. Today botanists classify all of them in distinct but closely related families of the plant order Caryophyllales.

Perhaps the most dramatic example of a revised classification brought about by molecular systematics is *Nelumbo*, the water lotus. Cultivated for its beautiful flowers, distinctive seedpods, and edible underwater rhizomes, the lotus has been immortal-

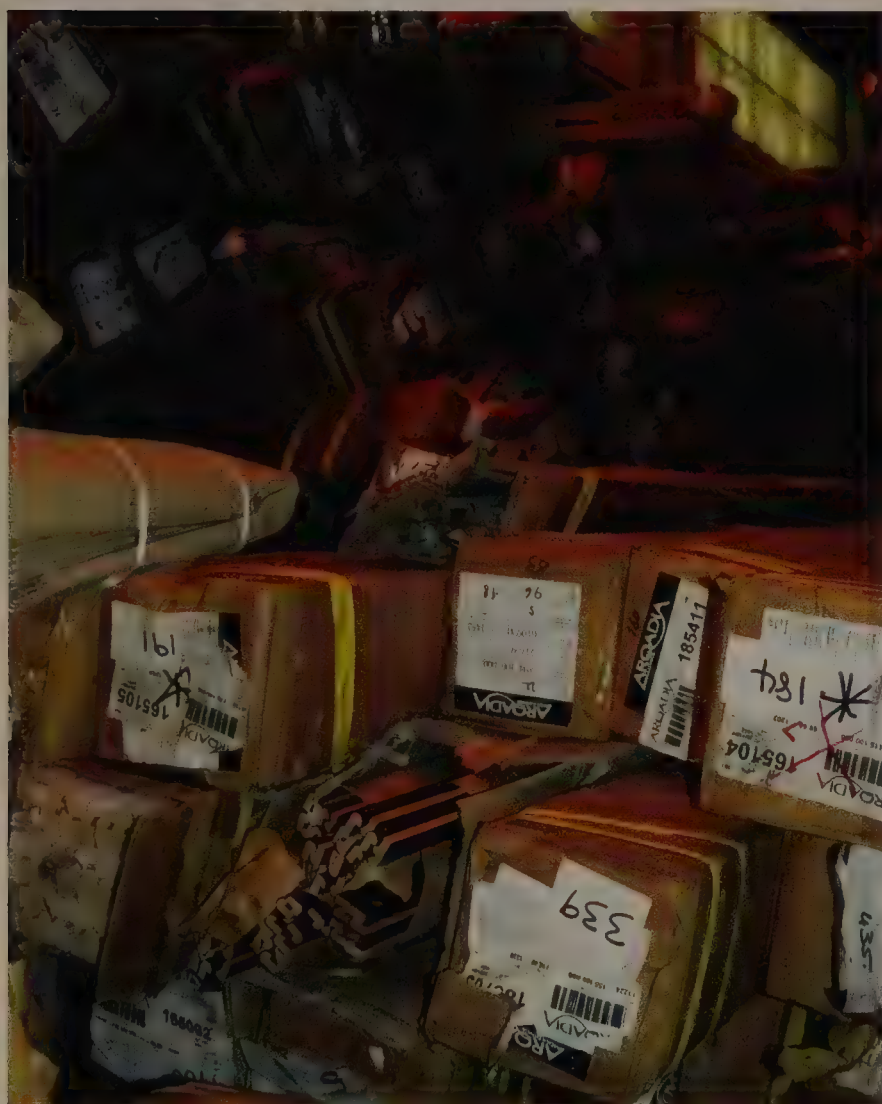
plane tree, along with the trees and shrubs in the family Proteaceae, which includes macadamia nuts and the showy-flowered members of the genus *Protea* [see photographs on opposite page].

Superficially, the plants have nothing in common. But when the molecular evidence suggested taking a closer look, botanists discovered that lotuses, proteas, and sycamores share similar floral and vegetative features. Moreover, the group was widespread during the Cretaceous period and probably more diverse in form than it is today, suggesting that plants intermediary among the sycamore, lotus, and protea might once have existed. Examples of surprising relationships revealed by recent molecular analyses go on and on, and include the close kinship of fungi to animals, cucumbers and begonias to oaks, orchids to asparagus, and violets to poinsettias, among many other remarkable glimpses into botanical genealogy.

My sci-fi story of a customs bust is a good way to understand how all that botanical detective work may one day pay off. Trade in a number of plants has been banned or restricted under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Among them are species of cactus, cycad, ginseng, orchid, palm, and tree fern. Full-grown adult specimens of those plants are usually easy for customs inspectors to spot during a search. But to thwart the inspectors, smugglers have been known to chop off the plants' leaves, then illegally import the bare stems under false names. The plants remain alive, of course, and will produce new leaves the following season, but the practice makes it nearly impossible for officials to correctly identify the plants or to take legal action.

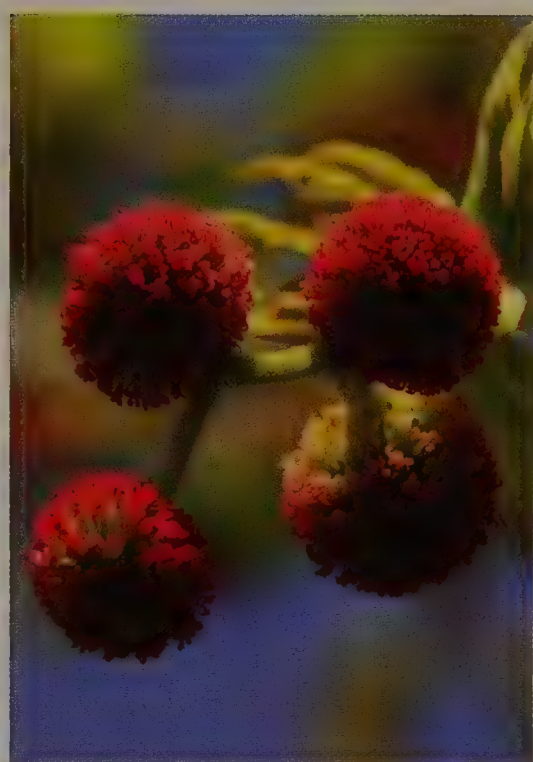
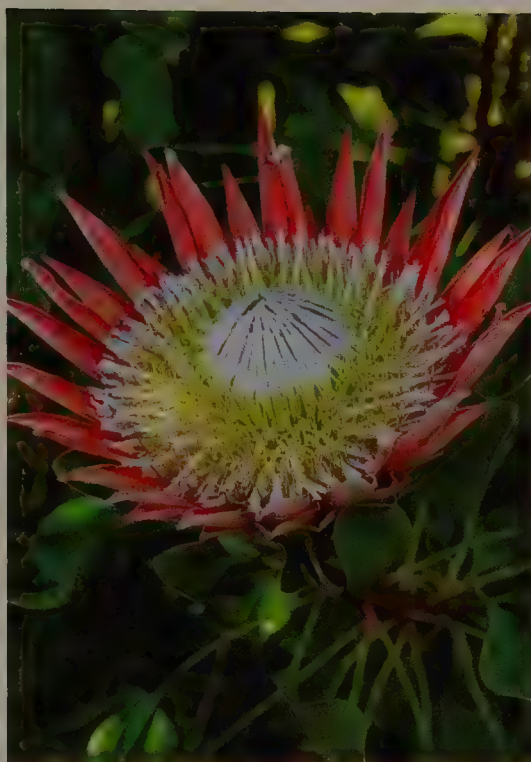
Identifying a plant from its DNA has several important advantages. First, the DNA of each species is distinct from any other; DNA is a unique identifier. Second, all nonreproductive cells of a given organism have the same complement of DNA. Testing any fragment of the organism—whether leaf, root, stem, or petal—is enough to identify the organism. Third, the DNA in each cell of the organism remains unchanged no matter what the current stage in the organism's life cycle—whether it be a plant in seedling or adult stage, a frog in larval or adult form, or a fungus in hyphal or mushroom phase.

The advantages of the bar-code project are even more pronounced. The bar code itself would presumably be just a unique indexing feature, one diagnostic part, of each cell's entire complement of DNA. A database of DNA bar codes for all species, if it were available, would simplify a customs



Illegal shipment of picture frames made from ramin, the common name for several species of protected hardwood trees in Southeast Asia, was intercepted in the United Kingdom in 2002 after arriving under a false species name. DNA bar coding could help customs officials verify the identity of imported natural products.

ized in Chinese paintings for centuries. Most people, including botanists, assumed it must be related to water lilies or to some other aquatic flowering plant. In fact, according to DNA-sequence data, the lotus is most closely related to *Platanus*, the sycamore or



Strange sisters: studies of plant genetics show that the water lotus (left), which botanists once classified with the water lily (not shown), is in fact closely related to the protea (middle) and the sycamore tree (flowers shown at right). That reclassification, along with several others, is shown graphically in the illustration on the next two pages.

inspector's job. He or she would sample a few cells of virtually any plant or plant fragment that came through the inspection station. The inspector's handheld scanner would then sequence the bar-code DNA, submit the bar code for comparison with the universal database online, assign the correct name to the plant material, and link to useful information about the species.

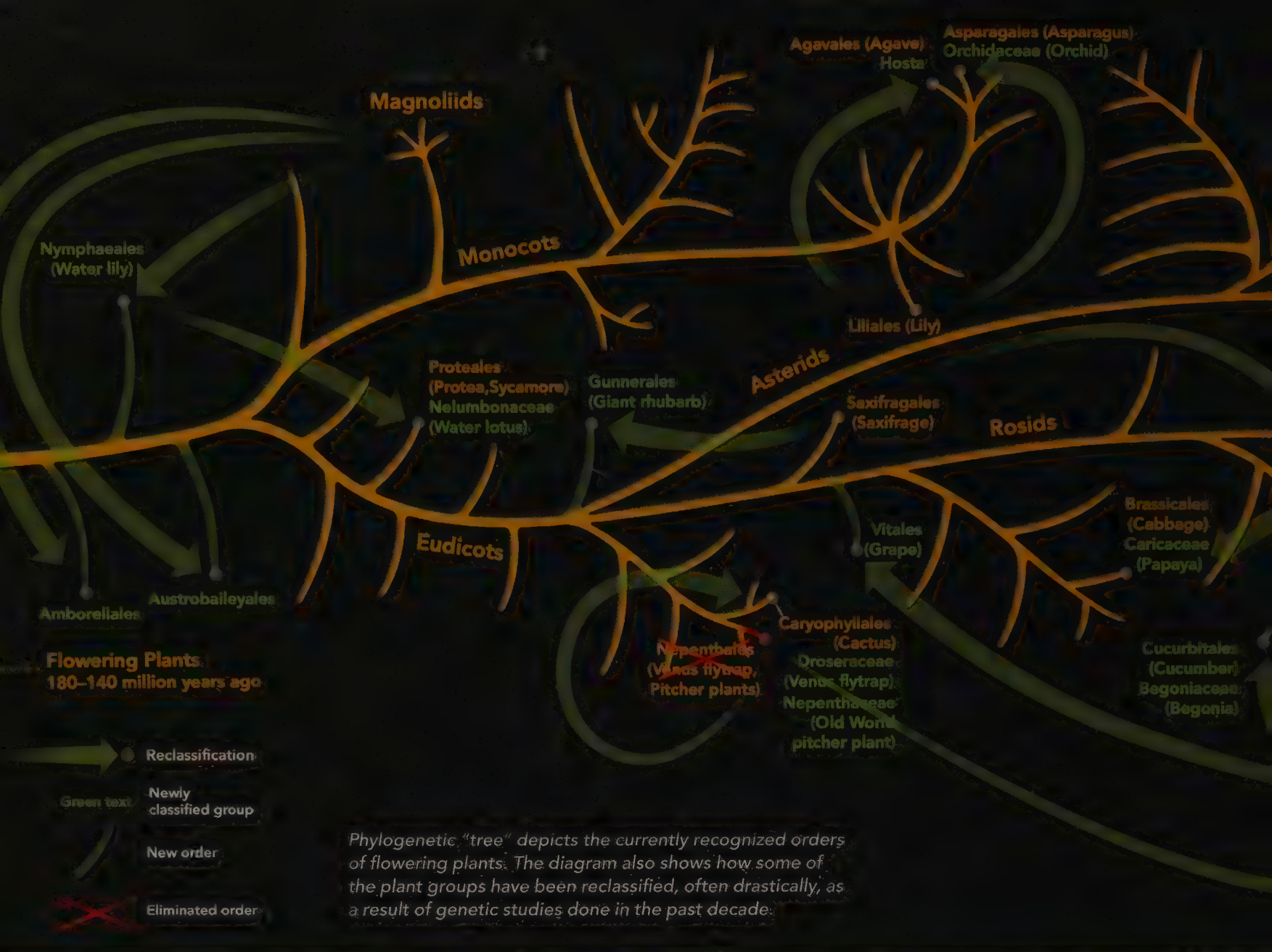
But the practical applications of DNA bar coding for plants are hardly limited to catching smugglers. I have developed a genetic test to distinguish the vanilla beans of various species. The beans look similar, but they are quite different in quality. Inferior species are occasionally sold—either fraudulently or mistakenly—as premium-quality species to manufacturers of vanilla extracts, a problem DNA bar coding will help eliminate. Consumers will be glad to hear that dried roots, leaves, and stems from medicinal plants can be identified with DNA bar coding before being sold as herbal supplements. Ecologists, too, will find the technique valuable in field surveys, because they will be able to include all plants in an area—whether big or small, easy or hard to identify.

Two other, more universal advantages of DNA bar coding are worth mentioning: it could extend the reach of expertise and make sophisticated biological knowledge more accessible to everyone. It has been estimated that biologists may have discovered and cataloged no more than 10 percent

of Earth's biota. Yet species are disappearing at an alarming rate. That leaves a lot of work to be done in a very short time by taxonomists. Yet taxonomy is a shrinking profession because of budget cuts at museums and academic institutions, and a trend away from organismal biology toward the study of life at the cellular and molecular levels. Moreover, the same taxonomists are asked all too often to devote substantial time and expertise to making routine identifications of well-known species.

With DNA bar coding, any organism could be identified by entry-level technicians. Experts could give up the time-consuming burden of making routine "dets," or determinations, and focus their energies instead on more substantial scientific tasks. No longer would just a few authorities have the skill and knowledge to distinguish all 600 species of *Amanita* mushrooms—some poisonous and some edible—from one another; instead, almost anyone could do it! Knowledge could be spread widely and available to all. Amateur field guides do a good job of guiding the nonspecialist, but portable bar-code readers, remotely linked to searchable databases of DNA bar codes, photographs, and species descriptions, could do even better.

So how far along is the scientific community in developing DNA bar-code databases? In zoology great progress has already been made. A single gene known as *cox1*, which occurs in the mitochondrial genome, has been chosen as the universal genetic



bar code for animals: nearly every animal species possesses a distinct version of *cox1*. Zoologists in laboratories around the world are sharing techniques for sequencing the gene, and are quickly amassing enormous numbers of *cox1* gene sequences from thousands of different species.

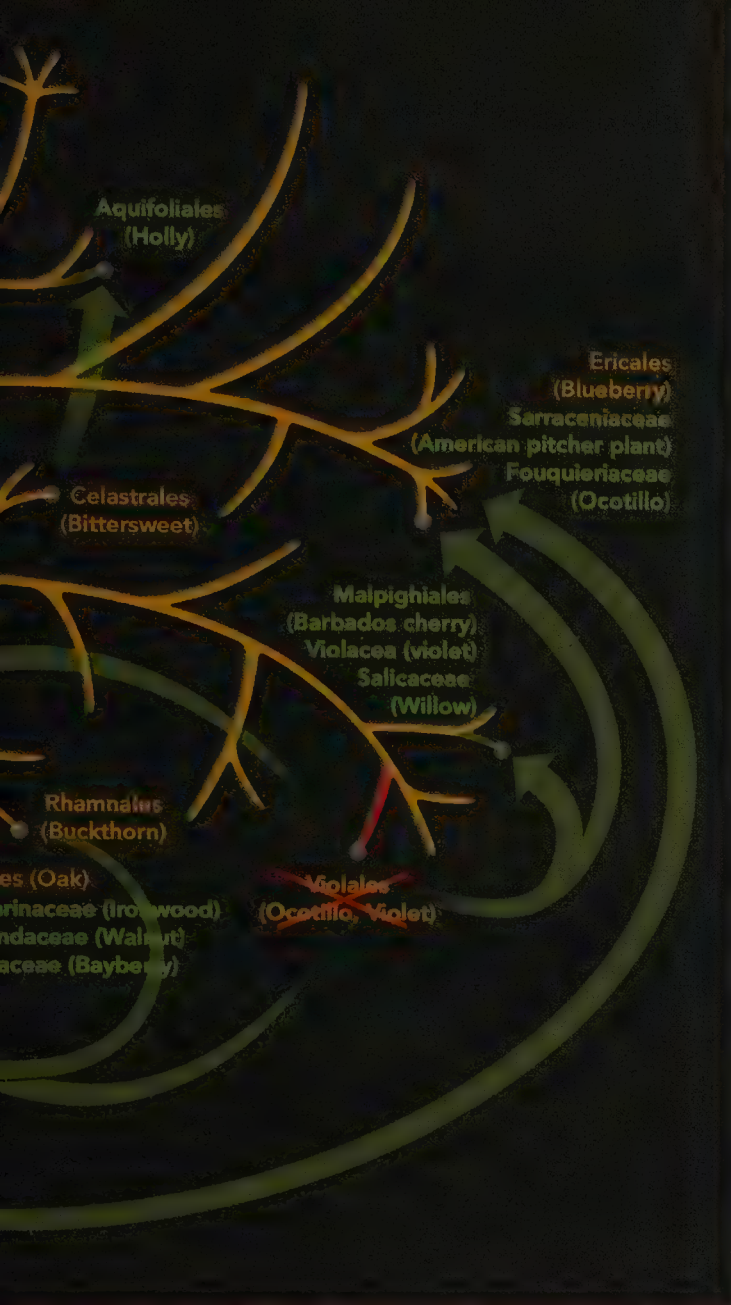
One of the best-publicized projects is the All Birds Barcoding Initiative, whose goal is to establish an archive of DNA bar codes for the approximately 10,000 known species of birds on Earth by 2010. Even more ambitious is FISH-BOL, aka the Fish Barcode of Life Initiative, which has already started to collect DNA bar codes for the world's more than 29,000 known fish species. FISH-BOL hopes to complete its collection within the next five years.

Unfortunately, the botanical community has not been as quick to jump into DNA bar coding as zoologists have. In part, the reason is that plants present unique challenges. Pressed and dried plant specimens in herbaria often yield their DNA less readily than do preserved animal specimens in museums. Moreover, animal species are most commonly defined by their reproductive isolation from one another, whereas many plant species can hybridize,

thereby blurring their genetic boundaries. Finally, the mitochondrial genome has evolved quite differently in plants than it has in animals. The *cox1* gene is not practical as a universal bar-code marker for photosynthetic organisms.

To address those problems, the Consortium for the Barcode of Life, a body of scientists representing natural-history museums, universities, and botanical gardens around the world, formed a plant working group in 2005. That group, on which I serve as vice-chair, is actively engaged in a two-phase project to find a plant gene, or small set of genes, comparable to *cox1* in animals, that can act as a bar code for all plant life. The first phase, completed in early 2006, aimed to identify five or more candidate gene regions from a small set of plants. The second phase is devoted to testing those candidates across the entire plant kingdom. There is consensus among the two dozen scientists in the group that the gene or genes should meet several criteria. The genes should be present in all plants, easy to sequence, as short as possible, and highly variable from plant to plant.

After several months of testing during our first



phase, we identified six candidate genes by comparing gene sequences from 122 plants, representing sixty-one closely related species pairs from across the entire plant tree of life. The candidates are all chloroplast genes—known as *accD*, *matK*, *ndhJ*, *rpoB*, *rpoC1*, and *YCF5*—most of which happen to code for proteins that play a role in photosynthesis. Now, in the second phase of the project, those six candidate genes are being sequenced in a broader selection of plants, including various conifers, cycads, ferns, and mosses, as well as monocot and dicot flowering plants. For example, in my laboratory we are sequencing the candidate genes for almost every species of the tropical fern genus *Elaphoglossum*, the conifer genus *Cupressus*, and the Hawaiian flowering plant genus *Labordia*.

My laboratory is also overseeing a complementary project to sequence the six candidate genes in all the vascular plant species of a fixed geographic region, rather than in scattered lineages throughout the entire plant kingdom. And where better to start than in one's own backyard? Our goal is to barcode every species of vascular plant—both native and exotic—within the fifty-acre forest at the New

York Botanical Garden. The forest has never been cut for agriculture and thus includes a rich diversity of plants: approximately 343 species in 246 genera from ninety-eight families. Each species is being newly collected, identified by at least two staff botanists, and pressed, to serve as a new voucher specimen for the herbarium. A sample of leaf tissue is preserved in silica gel and frozen to serve as a source of DNA. Those DNA samples are then added to the garden's permanent DNA library.

Many other such projects are taking place around the world, and as a whole the plant working group is making excellent progress. Within the coming months we expect to announce our recommendation for the gene or genes that will enable plant DNA bar coding to proceed.

In spite of the rapid gains DNA bar coding is making, support for it in the biological community is not unanimous. The strongest objection is that the technique is not foolproof. In practice, though, as technology develops, reliability should improve dramatically, and the problem should largely go away.

Modern biology is built around two primary paradigms. One centers on evolution and embraces the disciplines of Mendelian genetics, natural history, and systematics. The merger of those disciplines during the first half of the 1900s was called the modern synthesis. The second paradigm centers on gene expression and is the foundation of biochemistry, cell biology, molecular biology, and physiology. Those areas of research were brought together during the second half of the twentieth century under the unifying framework provided by the structure of DNA; that paradigm has been termed the molecular synthesis.

Biology is on the verge of a great new scientific revolution that will unite those two separate paradigms into a single program of research: the final synthesis. That new paradigm will enable molecular biologists in their laboratories and organismal biologists in the field to begin to communicate across disciplines.

Within botany, the blending of disciplines is already well underway. The molecular revolution has forced botanists to look more carefully at plants as well-known as the Venus flytrap and the water lotus. DNA bar coding promises further progress by providing new tools for scientists, amateur naturalists, and the public at large. Our children, armed with handheld Global Flora Scanners made possible by the molecular studies in full blossom today, will undoubtedly see and hopefully respect the diversity of life on this planet in ways that none of us can now imagine. □



On the Trail of the Ancestors

Anasazi pueblos lie in ruins across the American Southwest. What became of their inhabitants?

By Craig Childs

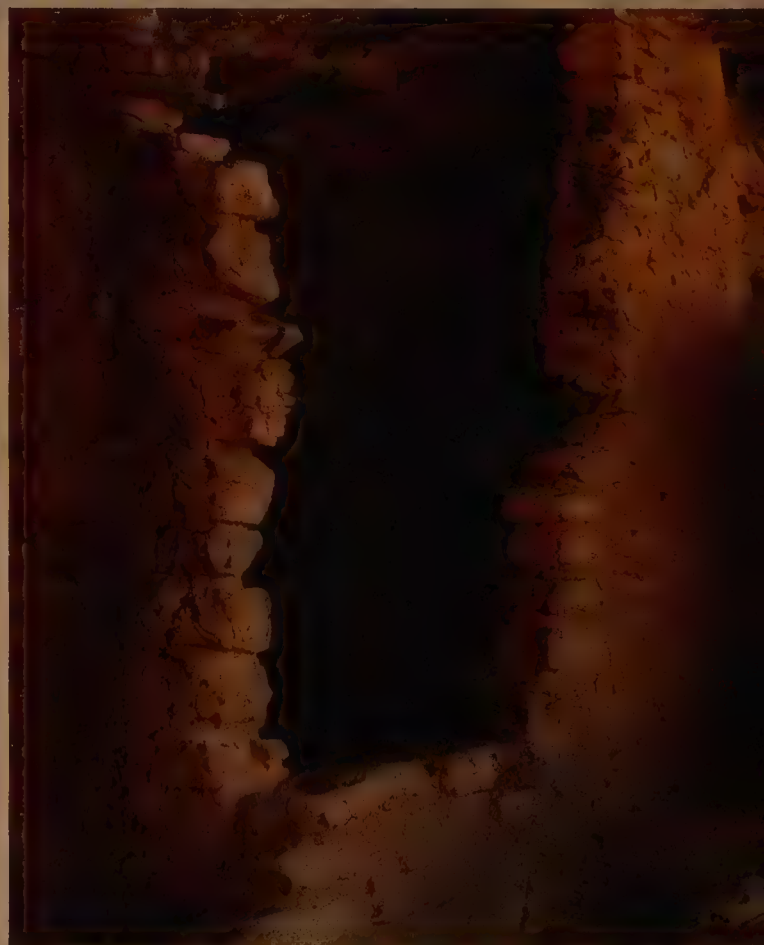
The Colorado Plateau is a 130,000-square-mile blister of land roughly centered on the Four Corners area, the dry confluence of Arizona, Utah, Colorado, and New Mexico. Its surface is incised with countless canyons and wrinkled into isolated mesas and mountain ranges that rise suddenly from the desert floor. The climate and the land are barely suited for scratching out a partial subsistence from agriculture. Yet the region is dotted with impressive ruins of pueblos, or towns, built of adobe and stone—often in the form of great communal blocks of apartments ensconced in valleys or tucked into cliffs. Some thousand years ago those dwellings, in such places as Chaco Canyon and Aztec, New Mexico; Mesa Verde, Colorado; and Canyon de Chelly, Arizona, housed a population numbering in the hundreds of thousands. The inhabitants, the so-called Anasazi, grew corn, traded pottery and textiles, and built great underground ceremonial chambers known as kivas.

Viewing the abandoned structures, most people assume this land must once have been better country to live in. But the climate was no different 1,000 years ago than it is today. Rainfall has always been unpredictable in the desert. It was just as dry at some times as it is now, and as wet at others; it was prone to the same scales of flooding. Farming seasons expanded and contracted like an accordion, leaving only slim margins for planting and growing. The secret of the Anasazi was that they had learned how and when to move.

For more than 10,000 years the Anasazi and their ancestors walked the climatic tightropes of the Colorado Plateau, chasing the rain, leaving their camps and settlements behind. Sporadic farming began some 4,000 years ago, as corn and other

subsidiary crops slowly made their way northward from southern Mexico. But even with the onset of agriculture, the Anasazi remained a wayfaring people. Small family groups and clans readily skirted around climate changes, transferring their settlements to high, wetter mesas, or down to the sun-baked lowlands, as the need arose. Rarely would a person have been born, grown old, and died in the same place.

When farming became more widespread, a thousand years ago, the Anasazi rose with it, reaching the civilized heights of extensive housing complexes and public architecture. Then suddenly, about A.D. 1300 and well before Europeans invaded the Americas, an especially prolonged drought appears



Cliff dwellings in Mesa Verde National Park, Colorado, right, were occupied by the Anasazi during the twelfth and thirteenth centuries A.D., but then abandoned. Top left: Anasazi potsherds and prehistoric corn cobs, Navajo National Monument, Arizona.

to have contributed to the social collapse of most of the pueblos in the Four Corners. But whether the great populations migrated away, fell victim to internecine warfare, or suffered some other fate remains a great mystery of the Southwest.

The truck tires gobbled at paprika-colored sand as we gunned our way across Antelope Mesa, in a corner of the Hopi reservation. The mesa is one of four principal ones spread over a thirty-mile stretch of northern Arizona, standing like castles in a moat of formidable desert. The other three are home to several thousand Hopi residents, but only a handful of isolated families live here, without phones, without postal addresses. It has not always been thus. In the fourteenth century, well after the Anasazi are commonly said to have disappeared, Antelope Mesa was a cultural center, bustling with trade, manufacture, and incoming migrants. By far the largest pueblos in the Southwest, each with as many as 4,000 rooms, were perched above its sharp edge.



Mike Yeatts, an archaeologist employed by the Hopi tribe, was driving me to one of those abandoned pueblos. "You see a lot of prehistoric pottery from this region traded throughout the Southwest," he explained as he drove. "I believe these people were involved in a major trade network, exporting their pottery down to the Phoenix Basin and over into the White Mountains." At the time, a distinctive irrigation culture known as the Hohokam farmed the Phoenix

Basin, while part-time agriculturalists, the Mogollon people, lived in the White Mountains of east-central Arizona. Each group created its own version of puebloan architecture.

In the early fourteenth century, populations around Antelope Mesa exploded as migrants arrived from disbanded settlements to the north. People were coming from Kayenta, a region of forested mesas and desert basins to the northwest. Others arrived from Mesa Verde, to the northeast, which had come apart at the seams and was left empty, and from





whatever was left of Chaco, where a remnant population was camped out in a deteriorating shell of public architecture.

We drove through groundswells of dunes tied down at their edges by rabbit-brush and ricegrass. In a tuck between two large billows of sand Yeatts stopped the truck. From here, we would continue on foot. As we walked, the dunes shrank and bedrock appeared from under the sand, whales of reddish stone barely breaching the surface.

I began to notice potsherds—luminous yellow-orange pieces, like little suns rising out of the ground. I reached down and picked up a piece of a bowl. Its warm, egg-yolk hue was completely unlike the cherry-colored red of the pottery I knew from north of here, and a far cry from the sharp black-on-white pottery that dominated the entire Colorado Plateau from about A.D. 900 until 1350. This pottery marked the arrival of the fourteenth century.

As I studied the sherd, I commented to Yeatts on its luster, its solidness.

“You find prehistoric coal mines below most of the sites out here,” Yeatts said. “They were using coal to fire their pottery. It was a technological shift that took them from red wares and black-on-whites to these yellow wares.”

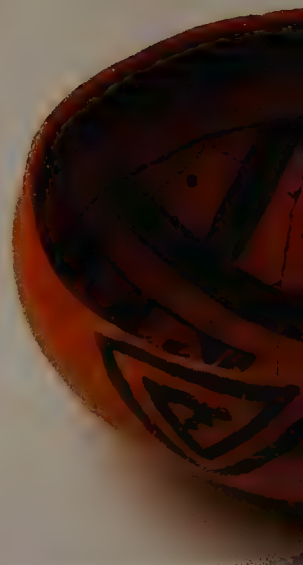
“The coal affected oxidation during firing?” I asked.

“Both oxidation and how long a high temperature was maintained,” Yeatts replied. “Wood-burning reaches the peak just as the fuel is about to collapse and after you’ve lost your main flame. Coal holds its shape so you can get that heat and keep air going into it for a much longer time. That is what gives you this wonderful color. Potters were probably using the same clay as that used for white wares, but it’s the technique that is different.”

Yeatts picked up two pieces and clinked them together, producing a melodious chime.

“Nearly porcelain,” he said.

It is no surprise that a new style of pottery appeared here. Antelope Mesa was the ultimate unification of the Colorado Plateau, two Anasazi



Elaborate complex of cliff dwellings in Navajo National Monument, Arizona, was built in the second half of the thirteenth century by the people of the Kayenta region, which lay across present-day southeastern Utah and north-eastern Arizona. The complex encompasses 135 rooms and was occupied for only a few generations.



Jeddito black-on-yellow bowl, dated to the late 1300s, was discovered in Verde Valley, in central Arizona. The bowl came from Antelope Mesa, some 125 miles to the northeast, presumably through trade. The nearly ceramic-like hardness and yellow base color result from firing the clay with coal, which maintains a high temperature longer than wood.

halves—east and west—coming together. Heading south, the people of Mesa Verde and Kayenta no doubt mixed in their exodus. Where travelers mingle and cultures touch each other, imagination and invention flourish. As much as drought was a push, urging people out of Kayenta and the Four Corners, the lure of growing civilization here in the south must have exerted a strong pull. Even today the place is legendary among the Hopi for once having had high-quality textiles, beautiful ceramics, and busy ceremonies.

Yeatts and his colleagues had been working for years putting together a map of just one of the pueblos at Antelope Mesa, recording evidence for thousands of rooms within a series of perimeter walls. I walked to the top of the ruins, enthralled by how a village could have grown into such a massive pueblo, one that continued to prosper until as late as the eighteenth century before it was finally abandoned. Unlike most Anasazi settlements that have lain empty for many centuries, pueblos on Antelope Mesa and the Hopi mesas have been occupied well into historic times. The Hopi themselves are the direct descendants of ancient pueblo dwellers.

As Yeatts and I walked through the ruins, I asked him about ancestry—the relationship between Hopi and Anasazi. But when I used the word *Anasazi*, Yeatts put his hands in his pockets and looked uncomfortably at the ground.

“I’m sorry,” I said. “I wasn’t thinking.” Here, I knew, *Anasazi* was an insult.

The word was crafted by the Navajo, who in the 1800s were paid by white men to dig skeletons and pots out of the desert. The Navajo probably did not arrive in the Southwest until the mid-sixteenth century, nomads from present-day southeast Alaska and British Columbia. Their reservation now dwarfs and surrounds the Hopi reservation. For a long time *Anasazi* was romantically and incorrectly thought to mean “old ones.” It actually means “enemy ancestors,” a term full of political innuendo and slippery history.

“You understand why it is an unpopular term,” Yeatts said. “It is not a name the Hopi chose.”

“I understand,” I told him, aware that the word implies people are dead and gone, the land abandoned, available for anyone who wants it.

“But *Anasazi* is also a very rich term, full of history,” I said.

“The Southwest has many conflicting histories to contend with,” Yeatts admitted.

The bar was small and smelled of cigarette smoke. A few men played a slow game of pool in the back. On the trail of Anasazi who might have migrated south of the border, we had driven out of the desert and up the pine-bristled slope of the Sierra Madre of northern Mexico. A southern group of the Mogollon people once lived in this region. There were four of us, including my wife, Regan, and two college students, Darin and Eugene, both studying Southwest archaeology.

Sixty or so years old, the bartender standing across from us was gregarious. We had been talking with



Remnants of a thirteenth-century wood balcony at Mesa Verde have been exceptionally well preserved by the arid climate.



Ceremonial double mug unearthed at Mesa Verde is an unusual shape, but its black-on-white style dominated the Colorado Plateau from about A.D. 900 until 1350.

him for half an hour, drinking beer and exchanging news. We told him where we had been, a couple of weeks in the mountains, camping out beyond the roads, and spending some time at Paquimé, also known as Casas Grandes, the great pueblo ruin of northwestern Chihuahua.

With both hands spread on the bar, Gilberto the bartender asked what we were looking for out there in the *barrancas*, the canyons.

I told him we were travelers interested in wilderness—"la tierra salvaje," the wild land.

Gilberto nodded and asked if we were looking for treasure, for Sierra Madre gold. We all laughed, a little uneasy.

Darin, sitting on the stool to my left, turned a cigarette in his mouth and leaned forward to meet Gilberto's outstretched lighter. "We're looking for the dead," Darin said, in Spanish.

"The dead?" Gilberto asked, suddenly reserved.

"We're interested in ruins, in prehistory," Darin said. "We're students of archaeology."

Gilberto studied us for a moment. He had a large brass belt buckle emblazoned with a leaping buck. He was a hunter. He would have known about the countryside, the farther places.

"People are nervous about archaeologists here," he said. "They fear the government might confiscate their land."

Eugene, brooding to my right, laughed darkly as he swiveled his beer bottle between his fingers. "We are not archaeologists," he said. He looked down the line of us and asked, "How do you say in Spanish that we're just glorified vagabonds?"

Regan explained that these two were students,

and she and I were their instructors for a semester of field studies. But more so, we were friends, traveling companions.

"We are careful people," Regan said. Her voice was calm, its tone asking him please not to judge us for our boldness, or for our broken Spanish.

"We understand these places are very delicate, very personal," she said. "How do you say, sensitive?"

Gilberto nodded slowly. "*Frágil*," he said.

"*Sí, frágil*," Regan said.

The bar was quiet for a moment.

Gilberto smiled and said, "People around here call them the Anasazi."

I sat forward over my beer. "Anasazi?" I asked.

Gilberto laughed. "It is the incorrect term, of course. People here are ignorant when it comes to archaeology."

I was impressed that he knew enough about archaeology to know that *Anasazi* is a displaced word down here. He considered us for a moment, and then said he wanted to show us something. He excused himself and slipped out from behind the bar.

"Maybe we shouldn't have told him all that," Eugene said down into his beer. "Now we're going to have *federales* in here asking for papers."

"I think he has something to show us," Regan said, taking the bartender at his word.

Ten minutes later Gilberto returned, carrying a worn manila envelope. He lit a cigarette, then pulled a stack of photographs out and laid them in front of us. The photo on top, the size of an index card, showed Gilberto with a dead white-tailed deer. It was a buck, three points to each antler, and in the photo Gilberto held the head upright. We all nodded approvingly. A good kill.

"Through the heart," he said, pointing his cigarette at the deer.

He had gone hunting in the *barrancas*. The deer were deep in those canyons that run through the Sierra. He had traveled a long way on foot, following deer tracks into difficult places. He turned to the next black-and-white photograph.

It pictured a cliff dwelling, a bank of walls and dark roof beams tucked back into a cave. I had not seen any cliff dwellings of such stature south of those constructed in the fourteenth century just below the Mogollon Rim. Migrants from the Four Corners into east-central Arizona had lived in cliffs along that rugged escarpment, which forms the southern limit of the Colorado Plateau. I now believed I was seeing evidence of these same migrants even farther south. We leaned in from our bar stools as if Gilberto had just opened a treasure chest.

The site he had photographed had thirty rooms, maybe more. It was three stories tall at the back end, where adobe walls snuggled against a soot-blackened cave ceiling. It looked like the cliff dwellings of the Anasazi, similar in scale and design to the largest structures at Four Corners. T-shaped doors, a feature of many ancient Southwest pueblos, were strung across the buildings like standards.

The next photograph plainly showed a different site. "How many cliff dwellings are there?" I asked. Gilberto said they were everywhere.

Gilberto arranged five shot glasses along the bar. He pulled out a bottle of sotol he said was bootleg, and poured each of us a drink. Gratis.

I looked at Gilberto, who was smiling. I lifted the shot glass to him and then touched it to my lips. The sotol, the traditional highlands drink distilled from the heart of a saw-bladed, yuccalike plant, tasted smoky and as hard as gasoline.

If we wanted to know, he said, he would tell us where the ruins are.

Yes, we wanted to know.



Cliff dwellings with rounded storage chambers lie deep in a canyon of the Sierra Madre of northern Mexico. The author believes they may have been built in part by Anasazi migrants from the U.S. Southwest, though pueblo ruins in the region are commonly attributed to the Mogollon culture, which was contemporary with that of the Anasazi.

He explained that a maze of dirt roads leads into the Sierra, until finally there is only one road, in places hardly a road. There is a rancher named José who lives there, a lonely, strange man, but very hospitable. In the canyons beyond where José runs cattle are the cliff dwellings.

Gilberto placed his fist against his heart. "This is a very important place in my life," he said.

I told him we would be careful. He poured another round.

We traveled across mountainous terrain with a couple of weeks' worth of supplies on our backs. The way was broken up by fathomless canyons, with no trails but the ones left by animals. Brushy forests of Mexican pines, walnut trees, and big-toothed maples grew along the drainages where we set camps. Unfamiliar bird calls spilled from the canopy like silver coins.

Just as Gilberto had said, cliff dwellings were everywhere in these canyons, packed into nearly every cave we spotted, biscuit-colored adobe walls notched with black windows and conspicuous T-shaped doorways. The number of T shapes was startling, crowds of them of many sizes, some as small as dollhouse doors.

We climbed to these towering cliff dwellings and walked awestruck through their rooms and hallways. Some buildings were three stories tall, cave ceilings black with wood smoke. With frayed parts of baskets on the floors and painted bits of murals peeling off the walls, they appeared not to have been touched for centuries. As we climbed through thickets of poison ivy, as we cooked meals at night, as we gathered water from springs, there was a constant sense that we were in someone else's house.

Even when we got drunk one night on a bottle of Gilberto's bootleg sotol we had packed in, two of us took off in the dark and found a ruin. Walking shoulder to shoulder through its rooms in the beam of a headlamp, we were suddenly sobered, hearing nothing but our own breath in the gaunt quarters. □

This article was adapted from Craig Childs's book *House of Rain: Tracking a Vanished Civilization across the American Southwest*, which is being published by Little, Brown and Company.



T-shaped doorway in the Sierra Madre of Mexico, constructed in about A.D. 1400, resembles many others that occur in the U.S. Southwest. The purpose and significance of the design are unknown.

*Chrysalis: Maria Sibylla Merian
and the Secrets of Metamorphosis*
by Kim Todd
Harcourt, Inc.; \$27.00

Surinam, a steamy wedge of land on the northeast edge of South America, is no destination for the casual traveler even today. Imagine, then, what it was like in June 1699, when fifty-two-year-old Maria Sibylla Merian, her luggage packed with notebooks and art supplies, left Holland, bound for the New World. At a time in which most women her age with comfortable incomes and grown children looked forward to catching up on their reading or needlework, she abandoned the sedate townhouses of Amsterdam for the mangrove swamps of a virtually uncharted frontier colony. Odder still, Merian went in search of—of all things—caterpillars, not exactly the fabled hidden treasures of El Dorado.

Since childhood, this daughter of a prosperous Frankfurt publisher had been fascinated by wiggly creatures. Later she became interested most of all in the curious ways they changed form. She trapped them in boxes and brought them indoors, then kept careful records as they wove cocoons, worked mysteries inside silken shrouds, and re-entered the world, miraculously transformed. By the time she was in her thirties, she had published two books on caterpillars, as prized by nature lovers and bibliophiles in her time as they are today.

But it is her voyage to the New World that assured Merian's place in history. Assisted by her twenty-one-year-old daughter Dorothea, she spent two years in the Surinamese jungles and plantations, observing, collecting, and recording her observations in her drawings and watercolors. The lush environment dazzled her, and her

sketchpads quickly filled not only with caterpillars, butterflies, and moths, but also with all kinds of unfamiliar animals: scarlet ibis (which she regarded as a species of flamingo), opossums, and even cockroaches.

In 1705, four years after her return from the tropics, Merian's magnum opus on the insects of Surinam was ready for the presses. It is remarkable not only for the beauty and skill of its



Engraving of Maria Sibylla Merian's 1705 painting of the life cycle of the white witch moth

artwork and its descriptive text, but also for the presentation of its subject matter. Contemporary illustrations of insects usually showed them as objects abstracted from their natural surroundings, as indeed the artists' models often were: portraits of butterflies, for instance, relied on dead specimens pinned to a board.

In contrast, Merian's drawings show insects as she saw them in vivo. A caterpillar appears alongside the butterfly or moth it turns into, perched on the plants it eats, and among the branches on which it pupates. Most notably, her books express an ecological sensibility

By Laurence A. Marschall

that place her, among naturalists, two centuries ahead of her time.

Biographer Kim Todd, author of the award-winning *Tinkering with Eden*, does more than just present such facts and spin a lively tale. Her prose imaginatively evokes the bustle of eighteenth-century Holland and the languid torpor of the South American rainforests, placing Merian in the intellectual, political, and social context of her times. A few color reproductions of Merian's watercolors give the reader a taste of her genius, though the small size of today's trade books only hints at the magnificent folio pages of the originals.

*Aldo Leopold's Odyssey:
Rediscovering the Author of
A Sand County Almanac*
by Julianne Lutz Newton
Island Press; \$32.95

Aldo Leopold's career began at a critical time in the environmental history of the United States. In 1909, as a young man fresh from Yale University and newly minted as a forester with the USDA Forest Service in Arizona, he entered an America transformed by a century of progress. The last vestiges of frontier were disappearing. The prairies had been cleared to make way for cash crops. Family farming was giving way to agribusiness, and people were leaving the rural homesteads of their parents and grandparents for factory jobs in the cities.

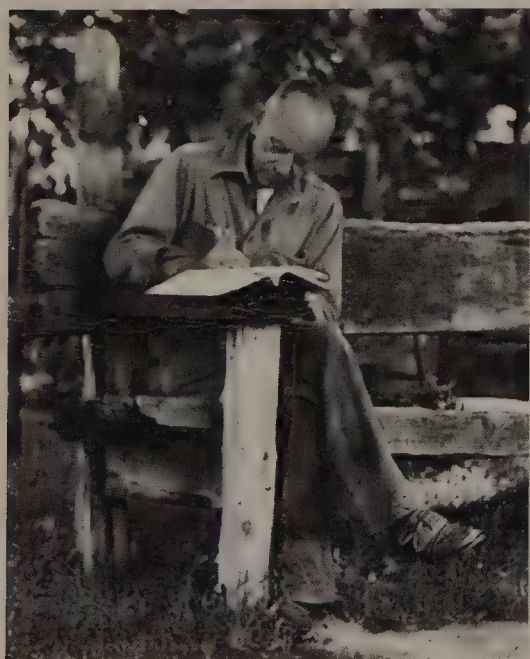
What to make of all this was a matter of great public concern. Everyone knew that forests were thinning and wild animals were disappearing. The once-great herds of bison were no more, and the vast flocks of passenger pigeons, once seemingly inexhaustible, had been hunted to extinction in a matter of decades. If those losses were now cause for national remorse, what was to be done?

Under the leadership of outdoorsmen such as Teddy Roosevelt, the environment became a public issue for perhaps the first time. The task seemed straightforward: conserve the forests to continue

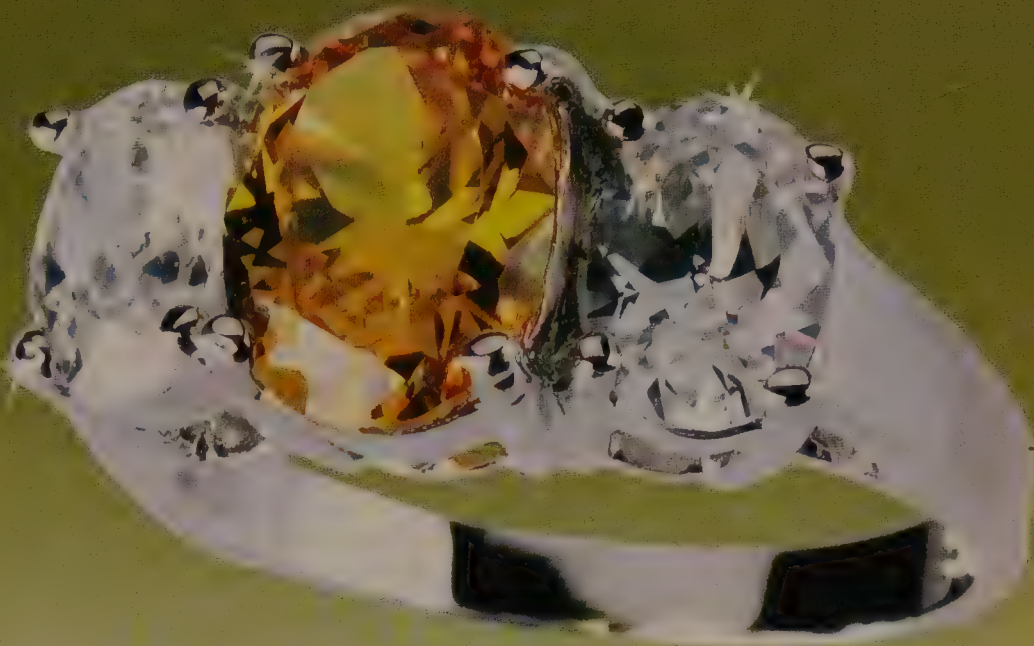
the harvest of timber, and manage game to ensure enough deer to hunt, birds to shoot, and trout to catch. People talked of conservation and wildlife as if the sins of the past could be remedied simply by better budgeting. And in 1909, no one embraced that cluster of ideas about conservation more enthusiastically than young Leopold.

If those views seem naively simplistic a century later, credit Leopold himself, who wrote and spoke about the critical problems of conservation for close to four decades. He authored a variety of professional articles and practical handbooks and, after 1933, spoke from a bully pulpit as a professor at the University of Wisconsin-Madison. Leopold's initial boosterism was soon tempered by the realization that one man's land management might be another's environmental destruction. A farmer who cleared weeds and brush for a profitable wheat crop might, at the same time, be removing plants that anchored soil against erosion and provided nesting places for game birds. How could the farmer be persuaded to adopt a balanced approach to his land? And what did "balance" mean in the first place?

Leopold's musings culminated in a book of essays, *A Sand County Almanac*, published shortly after his untimely death in 1948, at the age of sixty-one. *Sand County* treats the



Aldo Leopold, August 3, 1942



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critical questions of land stewardship with such lyricism and clarity that it has become a classic of the modern environmental movement. It is a mature work; Leopold did not come by his ideas in one blinding flash of enlightenment. He lived through the Great Depression, the years of the Dust Bowl, and two world wars. Most important, he played a crucial role in developing the new science of ecology, and his conservation philosophy stressed the connections between the animate and the inanimate. He was even alert to the social and political aspects of the environment.

In our times, when "ecology" is a household word, it's easy to lose sight of what the word implies: not just crunchy-granola sentiments and good intentions, but attention to the intricate network of cause and effect that ties together every element of the natural world. Julianne Lutz Newton's lucid and perceptive intellectual biography of the great conservationist recounts the long process by which Leopold came to this realization. Her book shows how to read *Sand County* as more than just a paean to all that is wild and wonderful.

*The First Copernican:
Georg Joachim Rheticus
and the Rise
of the Copernican Revolution*
by Dennis Danielson
Walker & Company; \$25.95

Without the prodding of others, two of the greatest works of Western science—Newton's *Principia* and Copernicus's *De revolutionibus*—might never have seen the light of day. Newton, an otherworldly genius, began to develop his laws of motion as early as 1664, but squirreled away his notes as if they were no more than old tax forms. So what made him publish? Some twenty years later, his friend Edmond Halley, of comet fame, was curious about whether Sir Isaac had any ideas on what kept the planets in orbit. Sir Isaac did.

In similar fashion, Copernicus was

too busy as a cleric and physician to pen more than a brief commentary about the sun-centered universe. His culture-changing book came about only under the urging of a young disciple, George Joachim Rheticus. Today Halley is almost as well-known as Newton, but Rheticus has gotten little more than passing mention.

Until now. Dennis Danielson, a professor of English at the University of British Columbia, has written a biography, both readable and scholarly, that restores Rheticus to his rightful position as a central intellect of the sixteenth century. Rheticus was only twenty-five when, in 1539, he first



Diagram of Nicolas Copernicus's Sun-centered solar system, as it appeared in the original manuscript of *De revolutionibus orbium coelestium* (1543)

traveled to Frauenburg (in what is now Poland) to study with Copernicus. Yet he was already a scholar of exceptional promise. A professorship of mathematics had been created expressly for him three years earlier at the University of Wittenberg.

Rheticus was enthusiastic about Copernicus's novel idea of how the universe was constructed, and within two years of his visit he had published a short précis on the Copernican theory, the *Narratio prima* ("First Account"), the first public exposition of Copernicanism for general readers. He also took over the task of getting Copernicus, by then frail and infirm, to set down the mathematical details of his theory

on paper. It was a difficult task, but the typeset pages arrived in 1543, as Copernicus lay on his deathbed.

For the rest of his life, Rheticus published seminal works on geometry, championed Copernicanism, and eventually pursued a second career as a medical doctor. But Rheticus never stayed long in one place. His sojourn with Copernicus was only one of several "research trips" he took to visit interesting thinkers. After Wittenberg he accepted a chair in Leipzig, only to leave soon afterward for Italy, to discuss mathematics with Girolamo Cardano. A natural restlessness, a taste for wine, the habit of living beyond his means, and a fondness for young men kept him on the move as the years went on. Yet he managed to remain remarkably productive until his death in 1574.

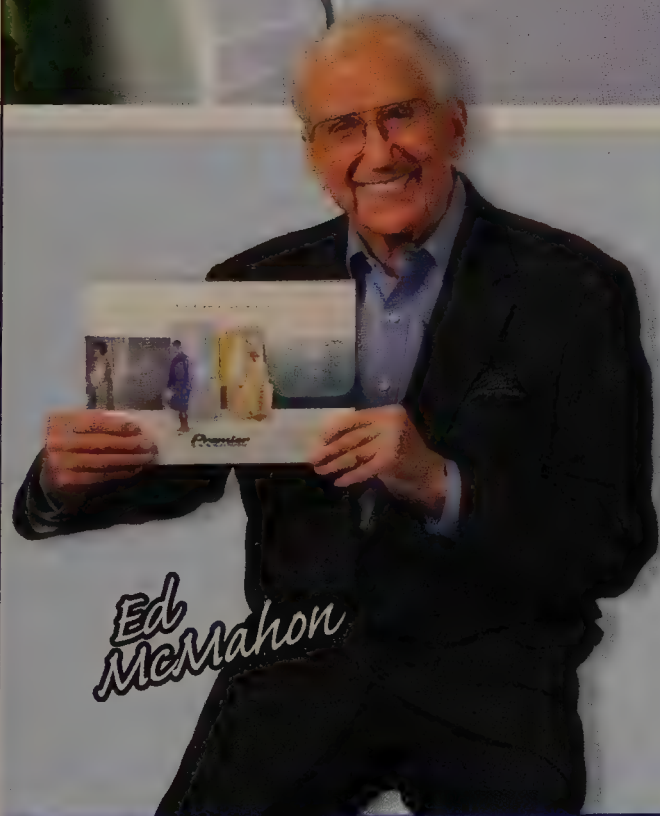
It's ironic that Rheticus's own astronomical work, unlike that of Copernicus, lay unfinished at Rheticus's death, and only twenty-two years later saw the light of day. Maybe it's doubly ironic that this work—calculating tables of trigonometric functions to at least ten decimal places by

hand—could be done today with a disposable electronic calculator. But in the late 1500s, the tables were an impressive advance, and as useful to the scientific enterprise, perhaps, as the invention of the slide rule. They remained essential to astronomers for centuries thereafter. For his role in the birth of mathematical astronomy, Rheticus justly deserves to be remembered, along with Halley, as one of the fathers—and midwives—of modern science.

LAURENCE A. MARSCHALL, author of *The Supernova Story*, is W.K.T. Sahn Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.

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Spin Control

How does swirling interstellar gas slow down enough to drain into a cosmic sink?

By Charles Liu

If our Sun turned into a black hole tomorrow, would Earth and the other planets suddenly fall into it?

Nope, no way. Black holes, weird as they are, don't "suck" matter. They're gravitational sinkholes, like any other object with mass, so from a distance they're no more destructive than any other lump of matter with an equivalent mass. As long as Earth maintains its angular momentum around the Sun (the product of its mass, orbital velocity, and distance from the Sun), our planet will stay serenely where it is.

Angular momentum is the key to all things spinning—from toy tops whirling on tables to giant planets revolving around distant suns to entire galaxies wheeling around a central black hole. You've doubtless seen figure skaters doing a scratch spin: starting with arms outstretched, they end up whirling dervishly as their arms are crossed close to their chests. One of the fundamental properties of physical systems is that (not counting friction) their angular momentum must stay the same. Thus, as their arms draw in (less distant mass), the skaters' spin velocities must increase.

The same relation holds for rotating liquids and gases. Take spiral galaxies, which look like cosmic pinwheels. The galaxy arms aren't solid. Rather, they're ephemeral patterns of gas flowing in the galaxy's disk; as the gas bunches up, it forms bright blue stars that outshine the regions between the arms. Any unprocessed gas stays in orbit, too, rather than funneling into the center—as long as it retains its angular momentum around the galaxy's center.

On Earth, friction is ubiquitous, and

with time it bleeds angular momentum away from just about every spinning thing, making the spin slow down and eventually stop. Scientists who rely on spinning lab equipment—a gyroscope, a centrifuge—have to think hard about how to reduce friction to keep things spinning. We astronomers have the opposite problem. In outer space, friction is rare, so angular momentum rarely goes away; objects and systems spinning in space tend to keep spinning forever. So when things actually do stop spinning and fall into their center of gravity, we have to think hard to understand why.

But what makes stopping such a big deal? For a star to form, most of a vast, spinning disk of interstellar gas many billions of miles across must condense into a spherical blob less than a thousandth its original diameter. But if there's no way for the disk to shed much of its initial angular momentum, no star can form. In particular, if some of the angular momentum of the protostellar gas that formed our infant solar system more than 4 billion years ago hadn't dissipated, the gas would have kept spinning and never have collected in a ball. The Sun would never have been born, and we wouldn't be here today.

So what causes the matter swirling around a protostar to lose its angular momentum, fall in on itself, and form a star? According to one long-held idea, gas moving at various speeds caused turbulence in the swirling matter, which dissipated the angular momentum. Alas, that idea has just been dashed by a swirling canister of fluid slightly taller than a kitchen blender—and

along with it, decades of astrophysical models have gone down the drain.

Of course, the aforementioned canister—designed and operated by a team of astronomers and plasma physicists led by Hantao Ji at Princeton University—is hardly your ordinary margarita-mixing machine. But forget that for a brief margarita moment, and think about what happens in an ordinary bar-top blender. The blender mixes the cocktail's ingredients because its rotating blades move its contents faster near the center and slower at the edge. That speed difference creates shear, which in turn creates turbulence—mini-whirlpools and eddies that interfere with the otherwise smooth-swirling flow. The turbulence sucks away the angular momentum of the protobeverage, which is mainly why the mixture stops spinning once the blades are stopped.

On Earth, the onset of turbulence depends on a quantity first defined by the English mathematician-engineer Osborne Reynolds. In 1883, while studying the flow of liquids in pipes, Reynolds determined that as flow speeds up and pipe diameters increase, so does the likelihood of turbulence; furthermore, the higher the density of the fluid—molasses, say, rather than water—the lower the likelihood of turbu-





lence. He condensed all those factors into a single critical ratio, now known as the Reynolds number.

When fluid—liquid or gas—flows in a circular pipe at a Reynolds number greater than about 2,300, the flow is usually turbulent. In a see-through pipe, for instance, eddies and irregular flows would be clearly visible. So engineers design waterworks and gas pipeline systems with Reynolds numbers no higher than about 2,000.

Beyond Earth, fluid flows can dwarf terrestrial ones, and their Reynolds numbers do, too. The flow speeds of gas in a protostellar disk can be many thousands of miles an hour; the density of the gas is much less than a billionth that of water, and the channels of fluid flow can be millions of miles wide. Those factors push the Reynolds number up into the millions, billions, and even trillions. At first glance, then, you'd expect such a gas disk to have tremendous fluid turbulence, enough to drain the angular momentum rapidly out of the disk, causing the gas to pour into a single core.

But astroscale gas flows differ from terrestrial ones in another hugely important way. Earthbound flows are physically bounded on all sides, by a container, by the ground, or even by air pressure.

The astronomical flows have no such boundaries, since they're held together only by gravity. So there's good reason to think that such a system does not act the same way as gas in a pipe or a margarita in a blender.

But how to prove it? No terrestrial laboratory can achieve the key astrophysical conditions—gargantuan Reynolds numbers in fluids spinning without physical boundaries. Ji and his colleagues, however, have come close. The experimenters placed water or water-glycerol mixtures in the space between two independently rotating cylinders (the larger one hollowed out to accommodate both the smaller one and the space for the liquid). Two pairs of rings, which formed the top and bottom of the inner space, could also move independently. The cylinders were spun rapidly, but at different speeds, to make the inside liquid swirl.

The apparatus enabled Ji and his colleagues to cause the Reynolds number of the fluid to reach 2 million—almost a thousand times higher than the point at which turbulence sets in on Earth, and approaching the numbers characteristic of astrophysical systems. Moreover, because of the freedom of movement of the rings at each end, Ji's team could simulate the unbounded conditions, the lack of physical “pushback,” at the top and bottom surfaces of a

protostellar gas disk more realistically than ever before. And guess what they observed? No turbulence. No loss of angular momentum. No fall-in. No model newborn star.

Well, obviously, stars do exist. So if fluid turbulence can't explain star formation, what can? It turns out that another, even more violent kind of rotating system may provide an answer.

When gas accumulates in a disk around a dense, compact object such as a black hole, the gas becomes ionized, hence electrically charged. The charged, swirling gas generates magnetic fields that interact with the gas particles, creating an instability that can produce the turbulence needed to drain away the angular momentum. The result is a vigorous flow of matter into the center of the system and a corresponding outward flow of energy in the form of X rays and high-speed jets of particles.

So if protostellar disks have substantial magnetic fields, stars can probably still be born. Such fields are sure to be present in the final stages of star formation. But observations of known protostellar disks have shown that they are made up mostly of dense, cold dust and gas—the exact opposite of the conditions needed to create magnetic fields. So unless someone can figure out how nature gets around that problem, we astronomers are still left with our disks (and our heads) spinning, not knowing how to get them to stop.

CHARLES LIU is a professor of astrophysics at the City University of New York and an associate with the American Museum of Natural History.

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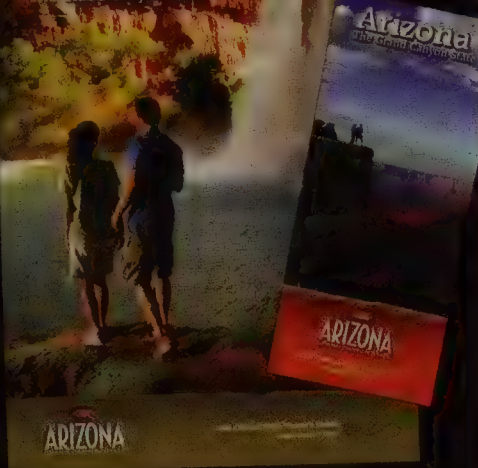
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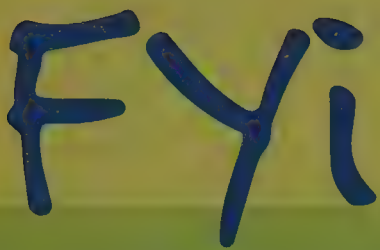


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New Tubes

By Robert Anderson

For anyone interested in geology, what could be more exciting than hiking inside a volcano, along tunnels that, until fairly recently, flowed with torrents of molten rock glowing yellow at about 2,000 degrees Fahrenheit? Around the world, there are dozens of volcanic regions where you can do just that. Mind you, the tunnels you hike in, called lava tubes, are not the main vents that conduct magma up from the bowels of the earth. Rather, they are channels that form beneath or on the slopes of some volcanoes when huge volumes of lava drain from the crater's reservoir.

The Big Island of Hawai'i is lava-tube central, an ideal place to explore old, emptied-out ones and to see new ones in action, making the Big Island bigger. On the Internet, start at Dave Bunnell's "Virtual Lava Tube" site ([\[earthgraphics.com/virtual_tube/virtube.html\]\(http://earthgraphics.com/virtual_tube/virtube.html\)\). Scroll down to the diagram by Carlene Allred and click on any one of thirty-six features of this alien world.](http://www.good</p>
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Sometimes unusual life-forms populate the area around the tubes. Kent Bridges, a botanist at the University of Hawai'i at Manoa, has prepared a virtual tour of the rainforest plants that grow along the walkway into the Thurston Lava Tube, one of the most accessible caves on the Big Island (www.botany.hawaii.edu/faculty/bridges/bigisland/thurston/thurston.htm). At Showcaves.com (www.showcaves.com/english/usa/caves/Kazumura.html) you can read about another of Hawai'i's popular attractions, Kazumura Cave, the longest tube system in the world, with a surveyed length of 36.8 miles.

The Web site of the U.S. Geological Survey's Hawaiian Volcano Observatory (hvo.wr.usgs.gov) has lots of good information on tubes still funneling lava to the sea. Click on "Kilauea" in the menu at the left, scroll down, and click on the link to a sketch that shows how

the tubes relate to the main plumbing of "perhaps the world's most active volcano." On the main menu, click on "Ocean Entry" (under "Volcanic Hazards") and scroll down to select "Collapse of new land into the sea." The section shows how lava builds new but remarkably unstable land.

For a look at how the tubes operate, as seen from above, check out the time-lapse volcano movies under "Kilauea," on the main menu. All the movies are informative, but don't miss the one near the bottom of the list, titled "East Lae'apuki Lava Delta Collapse": it records how, in just five hours, some thirty-four acres of newly created land vanished into the ocean.

In the continental United States, lava tubes occur throughout the volcanic regions of the west. At "Volcano World" learn about Ape Cave National Volcanic Monument, on the slope of Oregon's Mount St. Helens (volcano.und.edu/vwdocs/msh/ov/ovb/ovbac.html). At almost 2.5 miles in length, the cave is purportedly the longest intact stretch of lava tube in the continental U.S.

Outside the U.S., the Undara lava tubes in Queensland, Australia, are among the longest and they provide a perfect habitat for hordes of bats (www.undara.com.au/geo). The Web site of a travel company called EWP has photographs of lava tubes in the Azores (www.ewpnet.com/azores/caves.htm).

Lava tubes are not even limited to earthly destinations. The Oregon L⁵ society has links to information and images of lunar and Martian examples (www.oregonl5.org/lavatube). Such caves may offer human colonies the best protection from the harsh conditions on those distant worlds. Writing in *Astrobiology Magazine* (www.astrobio.net/news/modules.php?op=modload&name=News&file=article&sid=1260), Penelope J. Boston, an astrobiologist at New Mexico Tech in Socorro, considers "Life in a Lava Tube." Suddenly, that tube in Hawai'i is looking like a really great place to live.

ROBERT ANDERSON is a freelance science writer living in Los Angeles.

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THE SKY IN MARCH

By Joe Rao

Mercury becomes a morning object in March. It rises about an hour before the Sun and shines near the east-southeast horizon, well below and to the left of dimmer Mars. The Winged Messenger appears highest during the week of the 9th through the 15th, but is still no more than about eleven degrees above the horizon at sunrise. On the 13th Mercury glows modestly at magnitude +0.5, then brightens for the rest of the month. Unfortunately for observers in the northern United States, after the 15th it loses altitude, making it increasingly hard to see.

Venus is finally getting high enough in the west to command attention every clear evening after sunset. It is gaining prominence because as it traces its inside track around the Sun, it is gradually catching up with the Earth. Still well beyond the Sun as seen from our earthly vantage point, Venus appears too small and roundish to be a very interesting sight through a telescope.

Mars is shifting eastward throughout the month across the dim stars of the constellation Capricornus, the sea goat; viewed from near latitude forty degrees north, it rises just a few minutes before dawn. The Red Planet remains barely above the east-southeastern horizon during morning twilight. Shining at close to magnitude +1.2, it's the brightest object low in the southeast until Mercury appears.

Jupiter, in the southern part of the constellation Ophiuchus, the serpent holder, rises in the east-southeast around 1:45 A.M. local standard time on the 1st, and just before 1 A.M. local daylight time by the 31st. All month Jupiter lies about ten degrees from the bright star Antares, which rises above and to the right of the planet. The prime time to observe this majestic duo in the southern sky is just before dawn.

Saturn is in the constellation Leo, the lion, to the west, or right, of the "sickle," the backward-question-mark pattern. Saturn looks like a bright, yellowish-

white, zero-magnitude "star" that is already high in the eastern sky at dusk. Saturn makes two interesting encounters with the Moon this month. Early on the evening of the 1st, the nearly full Moon approaches to within less than one degree, to Saturn's left. Then on the evening of the 28th, Saturn lies directly under a waxing gibbous Moon as darkness falls. As the night progresses, note how the Moon creeps toward Saturn, making its closest approach later that night.

The **Moon** is full on the 3rd at 6:17 P.M. eastern standard time (EST). Our satellite wanes to last quarter on the 11th at 11:54 P.M. and to new on the 18th at 10:43 P.M. The Moon waxes to first quarter on the 25th at 2:16 P.M.

A total eclipse of the Moon takes place on the 3rd and lasts six hours and nine minutes. Across the Americas, when the Moon rises, the eclipse is already in progress. In fact, for much of the eastern third of the U.S. and east central

Canada, the Moon comes up completely immersed in the Earth's shadow. For the central U.S. and west-central Canada, the rising Moon is already exiting the dark umbral shadow of the Earth. From the western third of the U.S. and western Canada, little or no eclipse is visible. Totality begins at 5:44 P.M. EST and lasts seventy-four minutes.

A partial eclipse of the Sun takes place on the 19th, visible to varying degrees across much of central and eastern Asia, as well as throughout most of Alaska.

The **vernal equinox** takes place at 8:07 P.M. on the 20th. Spring begins in the Northern Hemisphere; autumn begins in the Southern Hemisphere.

Daylight saving time returns on the 11th for much of Canada and the U.S. Set clocks ahead one hour ("spring forward").

Unless otherwise noted, all times are eastern daylight time.



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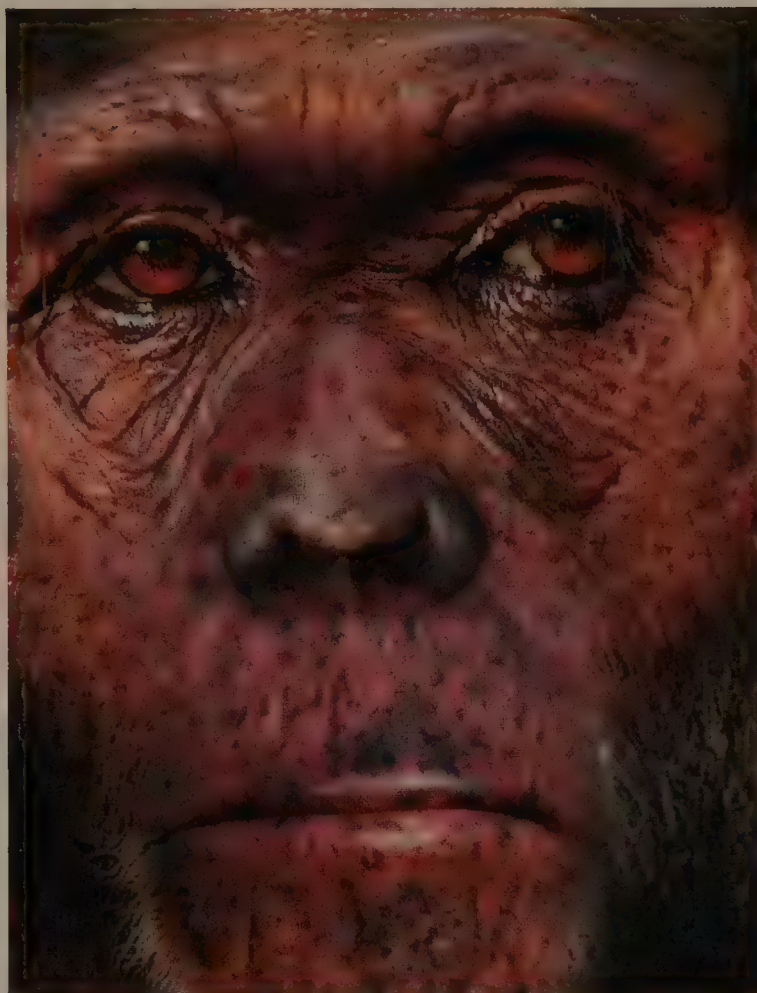


Human Evolution, Evolved

What makes us human? In the exciting new Anne and Bernard Spitzer Hall of Human Origins at the American Museum of Natural History, visitors learn that the answer lies, in large part, in our ability to think symbolically. Here, through the vivid imagery of sculpture, painting, video, and the ultimate set of symbols—language—the fascinating and still-unfolding story is told of how human beings came to be the distinct creatures we are—and how creativity lies at the heart of what sets us apart from the other animals.

On first entering the Spitzer Hall, visitors are greeted by the skeletons of a modern human and our chimpanzee and Neanderthal relatives, reminders that the search for our origins depends on the ever-expanding fossil record, gleaned from painstaking fieldwork the world over. But the eye-catching backdrop for this trio—huge panels picturing cells in mitosis and colorful chromosomes—sends the unmistakable message that cutting-edge DNA research has been added to the tool box, greatly enhancing the work of researchers decoding those finds. For example, DNA has been used to map modern humans' evolution and subsequent migration out of Africa, and to determine that despite all the differences in skin color, body type, and facial features, humans are genetically 99.9% the same.

The Spitzer Hall, the successor to the Museum's original Hall of Human Biology and Evolution, draws on the latest hominid finds by Museum scientists and their colleagues. Among them, the Hall boasts a vial of extremely rare 40,000-year-old Neanderthal DNA from the first laboratory in the world to have successfully extracted this elusive genetic material. The Hall is also home to a cast of the "Little Foot" fossil, the most complete skeleton of the human predecessor *Australopithecus*, found in South Africa in 1997. Only one other



Homo rudolfensis

IMAGE © VIKTOR DEAK

museum in the world displays a cast of "Little Foot."

Raising provocative questions about what makes us unique are an interactive feature on our closest animal relatives, the bonobos and chimpanzees, and their use of symbols to communicate; a robotic painter that "decides" when its creations are complete; and videos exploring intriguing behaviors of other species that resemble a human capacity for making tools, music, and art. All hint at some type of intelligence but fall short of what we think of as human.

The *Australopithecus afarensis* couple, featured in the original Hall, has been moved to give visitors a 360° view, a surprising sense of how small they were, and a chance to follow in their fossilized footsteps. The popular miniature of the French dig site La Micoque is preserved here too, as are copies of deer paintings from the cave of Lascaux,

now lit with flickering light as if seen with Ice Age torches. Three original dioramas have undergone renovation and a new one has been added: "Peking Man" about to be pounced upon by a hyena, representing "hominids as hunted, not hunters," says Ian Tattersall, Curator in the Division of Anthropology, who, along with Rob DeSalle, Co-Director of the Museum's Institute of Comparative Genomics, co-curated this permanent exhibition hall.

The Spitzer Hall of Human Origins presents the most up-to-date evidence of human evolution, bringing to bear both time-honored methods and the latest in genetic science to approach the most tantalizing mysteries of humankind: who we are, where we came from, and what is in store for the future of our species.

The Museum is deeply grateful to lead benefactors Anne and Bernard Spitzer, whose marvelous generosity inspired and made possible the new Spitzer Hall of Human Origins.

The Museum also extends its gratitude to The Mortimer D. Sackler Foundation, Inc., and Arlene and Arnold Goldstein for their generous support.

2007 ISAAC ASIMOV MEMORIAL DEBATE PIONEER ANOMALY

MONDAY, MARCH 26, 7:30 P.M.

The *Pioneer* spacecrafts were launched in the 1970s on trajectories that would send them past the outer planets and onward with enough speed to leave the solar system entirely. Now, however, their telemetry, does not match where our laws of physics say they should be—and the discrepancy is growing. Is this some unforeseen glitch of spacecraft design, or does it herald the need for a new law of physics? Join us as a

panel of experts discuss the “Pioneer Anomaly.”

Isaac Asimov, one of the most prolific and influential authors of our time, was a dear friend and supporter of the American Museum of Natural History. In his memory, the Hayden Planetarium is honored to host the annual Isaac Asimov Memorial Debate—generously endowed by relatives, friends, and admirers of Isaac Asimov and his work—bringing the finest minds in the world to the Museum each year to debate pressing questions on the frontier of scientific discovery. Proceeds from ticket sales of the Isaac Asimov Memorial Debates benefit the scientific and educational programs of the Hayden Planetarium.

DINOSAURS ALIVE!

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This large-screen adventure traces the steps of AMNH paleontologists, showcasing their remarkable findings about dinosaurs past—and present!

Feel the Impact of Cosmic Collisions

www.amnh.org

Get ready for amazing armchair adventures when you click on “Space Show” on the Museum’s home page, www.amnh.org. First, take in a tantalizing trailer for *Cosmic Collisions*, now playing at the Hayden Planetarium. From the crash of a meteorite that created the conditions that allowed humans to flourish to the inevitable (but far-distant) violent marriage of our galaxy with another, this Space Show literally takes you out of this world. Then, peek behind the scenes to learn how cutting-edge science and state-of-the-art digital technology brought to life these cataclysmic events that shaped, and continue to shape, our universe. An image gallery, absorbing text, educational links, and more add to the thrills found on this Web site.



PEOPLE AT THE AMNH

Liz Borda

Doctoral Candidate
Division of Invertebrate Zoology



JEAN-PIERRE HUOCOT

A woman who devotes her life to leeches inevitably has some explaining to do.

“What’s not to love?” says Liz Borda, who for six years has studied freshwater and terrestrial leeches with Mark Siddall, AMNH Associate Curator of *Annelida*, first as a Scientific Assistant and now as a doctoral candidate in biology at the City University of New York.

Liz wasn’t always this enthusiastic. In fact, the 31-year-old Queens, New York, native dismissed leeches as a nuisance when she first encountered them while studying lemurs in Madagascar during her junior year at Stony Brook University. She planned to study “cute, fuzzy primates,” not “slimy, squirming things that suck your blood.”

But such was the lure of fieldwork and a chance to work at the Museum, that in short order she was letting a leech feed on her finger as preparation for being bait in the field. “They’re easy to collect,” she says, “they come to you.” Her career has taken her to Southeast Asia, Chile, South Africa, Australia, the Seychelles, and Madagascar again, where she described a new species, *Malagabdella niarchosorum*, named for the Niarchos family, who helped underwrite the expedition.

Her ultimate goal is to continue doing research on terrestrial leeches and become a mentor as Dr. Siddall and others have been for her. In the meantime, she hopes to branch out with postdoctoral work on marine worms, whose hard jaws leave a fossil record, unlike the soft-bodied leeches, which only leave their mark on the living.

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY 

www.amnh.org



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Inka figure

EXHIBITIONS

Gold

Through August 19, 2007

This glittering exhibition explores the captivating story of the world's most desired metal. Extraordinary geological specimens, cultural objects, and interactive exhibits illuminate gold's timeless allure.

Gold is organized by the American Museum of Natural History, New York (www.amnh.org), in cooperation with The Houston Museum of Natural Science. This exhibition is proudly supported by The Tiffany & Co. Foundation, with additional support from American Express® Gold Card.

The Butterfly Conservatory

Through May 28, 2007

Visitors mingle with live, free-flying butterflies in a tropical environment.

Undersea Oasis:

Coral Reef Communities

Through January 13, 2008

Brilliant color photographs capture the dazzling invertebrate life that flourishes on coral reefs.

The presentation of this exhibition at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

GLOBAL WEEKENDS

Polar Weekend

Saturday and Sunday,

3/10 and 11, 1:00–5:00 p.m.

In recognition of International Polar Year 2007–2008, the Museum will host a two-day series of lectures, films, and family events.

Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, the New York City Council, and the New York City Department of Cultural Affairs.

Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

LECTURES

Uncertainty

Thursday, 3/1, 7:00 p.m.

Astrophysicist and science writer David Lindley discusses Werner Heisenberg's uncertainty principle and the scientific controversy it engendered.

Women of Discovery 2007

Saturday, 3/3, 1:00 p.m.

Meet the extraordinary recipients of the 2007 Wings WorldQuest's Women of Discovery Awards in the categories of earth, sea, air and space, humanity, film and exploration, courage, and lifetime achievement.



R. MICKENS/AMNH

In The Butterfly Conservatory

Big Fish

Tuesday, 3/6, 7:00 p.m.

Richard Ellis will discuss what scientists have learned from apex predators of the sea—

massive sharks past and present—and what might remain to be discovered.

Moa's Ark

Thursday, 3/29, 7:00 p.m.

Author, photographer, and adventurer Neville Peat discusses New Zealand's natural history and his latest book, *Kiwi: The People's Bird*, which chronicles efforts to protect this biological oddity and endangered national emblem.



The Search for "The Missing Link"

Wednesday, 3/14, 7:00 p.m.

By tracking fossil evidence, renowned paleontologist Alan Walker takes us back millions of years in search of our earliest human ancestor.

77th James Arthur Lecture

on the Evolution

of the Human Brain

Evolution and Development of Self Regulation

Monday, 3/19, 6:00 p.m.

Michael Posner, Professor Emeritus at the University of Oregon, examines the anatomy, neurology, and genetics behind humans' voluntary control of their thoughts, emotions, and actions.

WORKSHOP

Animal Drawing

Eight Thursdays, 3/22–5/10

7:00–9:00 p.m.

An intensive, after-hours drawing class among the dioramas and dinosaurs.

FAMILY AND CHILDREN'S PROGRAMS

Wild, Wild World: Predators

Saturday, 3/24

12:00 noon–1:00 p.m. and

2:00–3:00 p.m.

In this live-animal presentation, you'll get a close-up look at a golden eagle, alligator, python, and brown bear cub.

Dr. Nebula's Laboratory:

Life with Lucy

Saturday, 3/17, 2:00–3:00 p.m.

(Families with children ages 4 and up)

Join Dr. Nebula's apprentice, Scooter, as she explores the



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Friday, March 2

Eric Lewis



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HANDS-ON HUMAN ORIGINS Secrets of Skulls

Saturday, 3/17

11:00 a.m.–12:30 p.m.

(Ages 8–10, each child with one adult)

1:30–3:00 p.m. (Ages 10–12, each child with one adult)

Compare skull casts of early humans.

Discover DNA

Saturday, 3/24

11:00 a.m.–12:30 p.m.

(Ages 8–10, each child with one adult)

1:30–3:00 p.m. (Ages 10–12, each child with one adult)

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply. All programs are subject to change.

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ASTRONOMY PROGRAMS Robots in Space III (Advanced)

Three Wednesdays, 3/7–21

4:00–5:30 p.m. (Ages 8–10)

This class will help you hone your skills as an expert robot designer.

AstroFavorites: NASA

Astronaut Training Mission

Three Thursdays, 3/8–22

4:00–5:30 p.m.

(Ages 4–6, each child with one adult)

Learn about the human body in space, rocketry, and how astronauts become “space specialists.”

Visit the Space Station

Sunday, 3/25

11:00 a.m.–12:30 p.m. (Ages

4–5, each child with one adult)

1:30–3:00 p.m. (Ages 6–7, each child with one adult)

Come see what a day might be like living, working, and play-



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ing aboard the International Space Station.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe

Depths of Sky

Tuesday, 3/6, 6:30–7:30 p.m.

Special Tuesday

The Search for Life on Exoplanets

Tuesday, 3/13, 7:30 p.m.

Celestial Highlights

Spring Has Sprung

Tuesday, 3/27, 6:30–7:30 p.m.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions

Journey into deep space—well

beyond the calm face of the night sky—to explore cosmic collisions, hypersonic impacts that drive the dynamic formation of our universe. Narrated by Robert Redford.

Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum. Made possible through the generous support of CIT. *Cosmic Collisions* was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

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THE MUSEUM SHOPS

Notes from the Edge

By Robert R. Dunn

The first reports home from early European explorers in the tropics told of impenetrable jungles ("we hacked through a dense, green hell . . ."). But truth be told, the average tropical forest is fairly open. Large trees darken the forest floor, discouraging understory growth. What is impenetrable is the edge of the forest, where weedy species clamor for light, jostling into every empty space. The edge was the thorny tangle the explorers first confronted. Those who pushed on found a more inviting forest—albeit one that harbored malaria, the odd poisonous snake, and assorted other perils.

Those early encounters came to mind when I began teaching a summer field class in the Dominican Republic for college students from New York City. The course was held in a small patch of forest next to a seaside resort hotel (a location that posed multiple challenges, including how to keep students' attention when a topless bather walks by). One of my first goals was to get my charges used to the forest. They could appreciate nature, I reasoned, only if they learned to be comfortable in it.

So with practiced nonchalance, I began walking backward down a trail through the forest, twelve students in tow, waving my arms, pointing to snails, crabs, lizards, leaf forms, epiphytes. I was about to mention the amazing abilities of fungus-farming ants, when one of my waving arms hit something. I felt two sharp stabs in my neck, then a third, then a fourth. A most unscholarly series of expletives poured out of



my mouth, and I ran a few steps farther down the trail, away from the angry wasps.

Unfortunately, with me out of the picture, the wasps changed targets. When I looked back, all I could see were flailing arms and legs as my students took off in the other direction. A few of them were screaming. Then I heard a louder scream as someone at the front of the pack discovered one more of nature's secrets: another wasp nest. Soon, all the students were running toward me again. It went on like this for a while, the fleeing mob bouncing back and forth between nests, until three students were stung, several were crying, and one was protesting loudly, "I want to go home."



The class did get better (though there was that brief incident with a manta ray . . .), but I feared that for most of the students the forest would remain forbidding. The wasps, a species most at home in disturbed parts of the forest, were a part of the forest's edge, the tangle beside the well-worn trail where weedy species

thrive. The students would go home to tell their parents of a "dense, green hell." Worse, by virtue of its small size, our forest was more edge than middle, more barrier than invitation.

Had we come to the Dominican Republic several hundred years earlier, the forest would have been both taller, with old growth, as well as deeper, less carved up into small plots, and with an open understory crisscrossed by animal paths.

Later in the summer I invited the students on another trip into the forest, this one optional, by night. I didn't expect many volunteers; even my wife opted out. I arrived early at the meeting place. No one was there. I turned off my light and waited in the dark, listening to the wild calls of forest insects, and the wilder calls of tourists jumping into the hotel pool.

As I was about to give up, one student arrived, then another. Soon, almost everyone was present, headlamp on, ready to go in. We walked slowly along the path, fanning our lights across the leaves, looking for the shine of eyes (I also kept an eye out for wasps).

That night we saw hundreds of animals that had been hiding during the day: crabs, sleeping lizards, sleeping birds, snakes, and even, as everyone crowded around me, a small mammal. It stumbled away through the leaves and branches before we could identify it. We followed it, down off the trail, past the wasps and weeds, beyond the tangled edge. No one said a word.

ROBERT R. DUNN is an assistant professor of zoology at North Carolina State University in Raleigh, and a frequent contributor to *Natural History*. His most recent article ("Dig It!") appeared in the December 2006/January 2007 issue.

FIRST | FRIDAYS



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April 6 – Michelle Wyman

Executive Director for the US Office of ICLEI – Local Governments for Sustainability

Fast Forward – Examine the long-term development of the earth’s biodiversity into the future and the very essence of our collective, complex existence.

May 4 – Jared Leadbetter

Associate Professor of Environmental Microbiology, Caltech

Should I Stay or Should I Go? – Microbes: A migration success story that few of us have actually seen.

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June 1 – Nancy Knowlton

Director of the Center for Marine Biodiversity and Conservation

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² UNAIDS statistics, 2000, 2003.

³ *Nursing World*.

⁴ America's Most Admired Companies: annual survey, 2005, *FORTUNE* magazine, March 7, 2005.

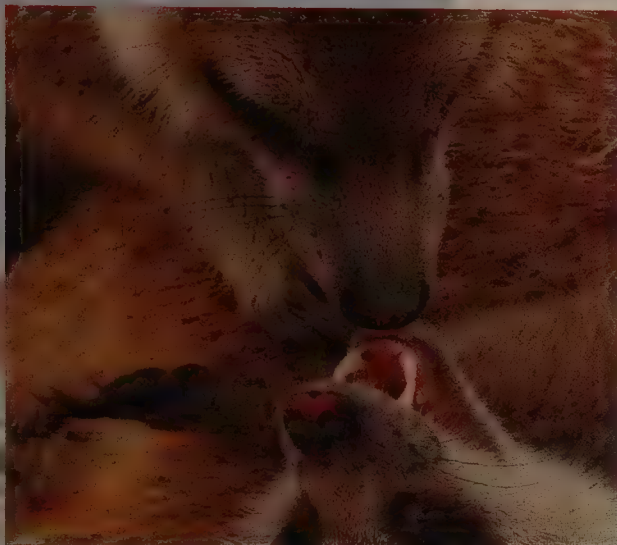
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FEATURES

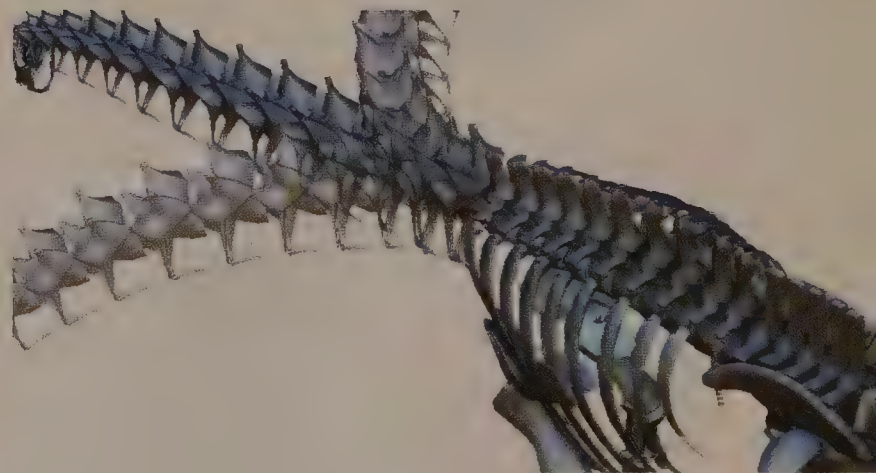
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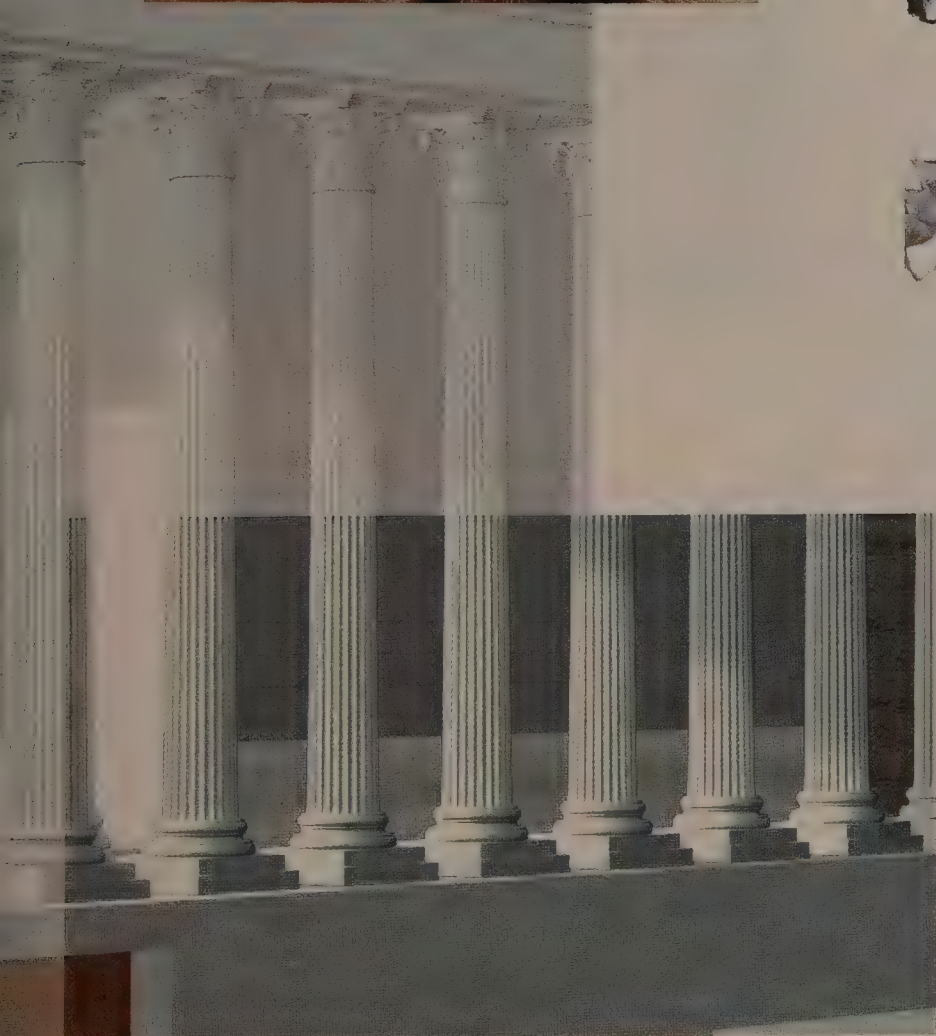
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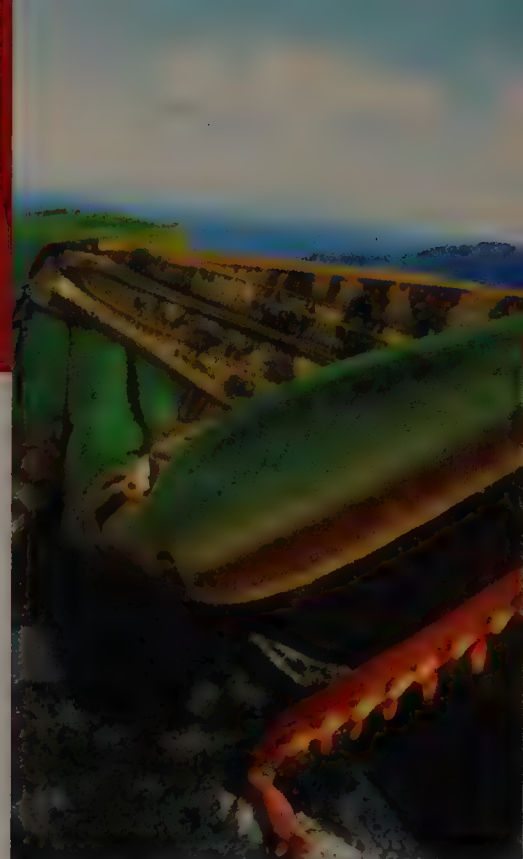
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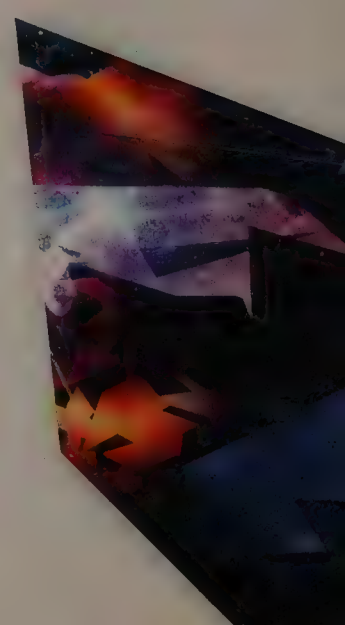
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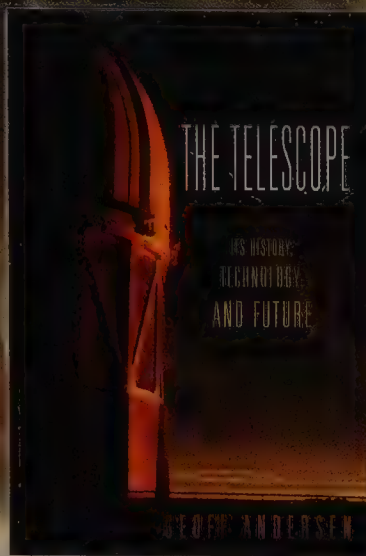
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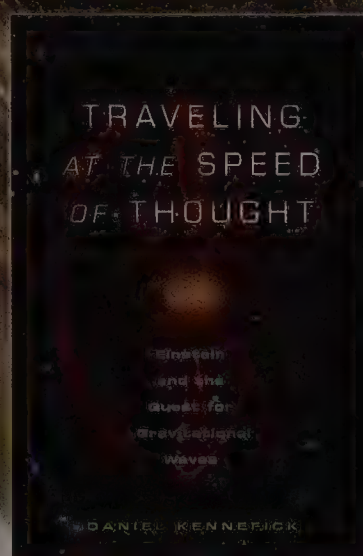
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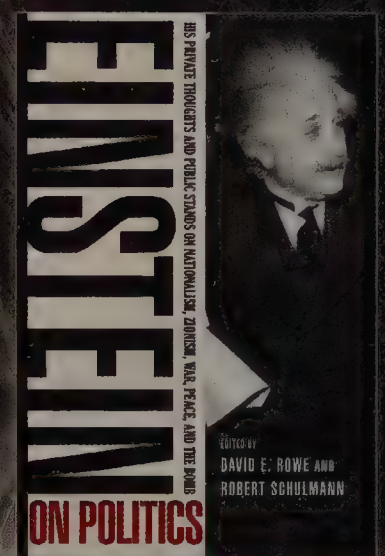
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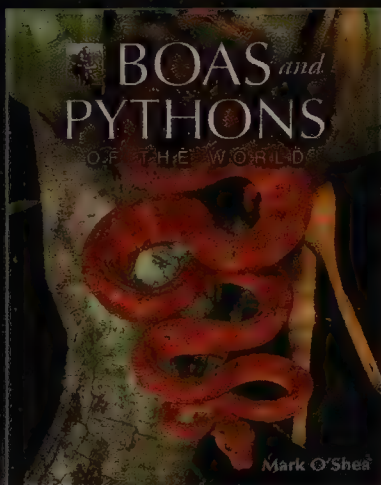
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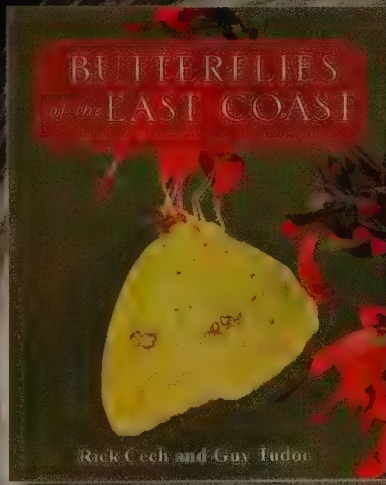
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THE NATURAL MOMENT

Bay of the Locust

Photograph by Satoshi Kuribayashi





◀ See preceding two pages



Who among us would act the same way in a noisy, sweaty crowd of strangers as we would, say, alone on a serene mountaintop? Locusts, too, change their behavior drastically when in the company of others, and they go so far as to change physically, as well. In fact, entomologists originally mistook what are now called the solitary and gregarious locust phases to be distinct species.

Locusts that live alone are much like your skittish, garden-variety grasshopper. But when they gather into a critical mass, the same insects begin changing their color, size, travel plans, and more. Ultimately billions can swarm together into black clouds of biblical proportions, capable of crossing oceans and destroying vast tracts of cropland. Even now, an outbreak of desert locusts (*Schistocerca gregaria*) threatens farmers in Eritrea and Sudan, on the coast of the Red Sea.

The migratory locust (*Locusta migratoria*) pictured here was alone when photographer Satoshi Kuribayashi spotted it on a hilltop near Hirado in the Nagasaki prefecture of Japan. Yet the unusual perspective serves as a reminder of how much power the insect can have. To make his image—one that seems almost “Photoshopped”—Kuribayashi designed a long, narrow tube to extend the focal length of his lens. With most lenses, the depth of field shrinks as one zooms in on a small subject. With the special equipment, though, Kuribayashi managed to get both the locust and the distant bay in focus.

Actual size of the lone mountaineer: about two inches.

—Erin Espelie

Multiple “Universes”

Writing these essays is the most exhilarating and exhausting thing I do in life. It is where I'm not only trying to convey information, I'm trying to convey love, the love of a subject. I don't always succeed, but when I do, I know of no greater source of professional happiness. —Neil deGrasse Tyson

Neil deGrasse Tyson (pictured below) is seldom at a loss for words. With his “Universe” column this month (“The Cosmic Perspective,” page 22), he’s written an even 100 columns of roughly 2,500 words each: more words, as he might put it, than there are miles from Earth to the Moon. But after he had patiently answered my questions about the column with a practiced ease, he told me he wanted to answer a question I didn’t ask. And then he spoke in almost halting syllables, groping for the sentences I’ve quoted above, about the passion he brings to his column about the cosmos.

Writing a “Universe” column, Tyson says, is “the closest thing I can imagine to giving birth. I know women would say, ‘You have no clue.’ But



so much is coming out of me that when I finish a column, I wonder if I can regenerate the energy and the emotion to do it again in thirty days.”

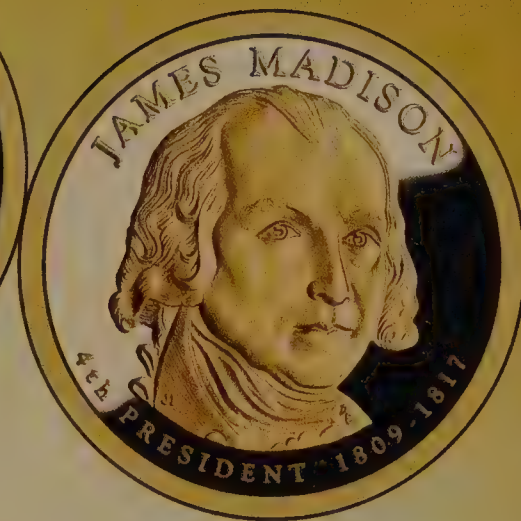
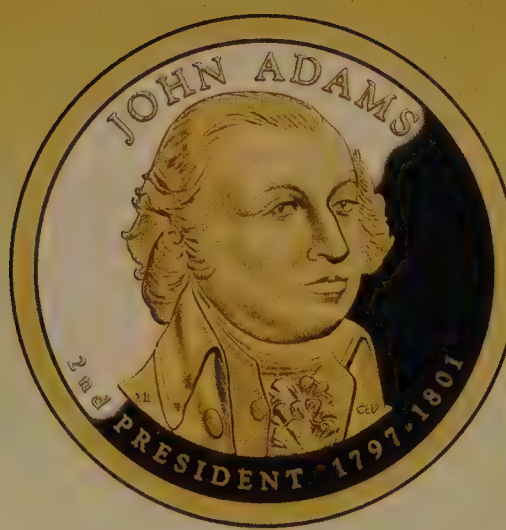
Tyson wrote his first column for *Natural History* in January 1995. The twelve years since then have been an extraordinarily exciting time for astrophysics, in part, he says, “because the biggest discovery in science was the discovery of dark energy, the fact that we live in an accelerating universe.” What about the next twelve years? “I want missions to the water-bearing objects in the solar system, which include Mars and some of the moons of Jupiter. I want to know whether there’s bacterial life, or any kind of life at all, thriving in those environments. That’s something that’s knowable in the next ten to fifteen years.”

• • •

Two of this month’s features complement major exhibitions at two of the nation’s most important museums of science and natural history. “Dinosaurs: Ancient Fossils, New Discoveries” opened March 30 at the Field Museum in Chicago and runs through September 3. In “The Sauropod Chronicles” (page 34), Richard A. Kissel, a paleontologist at the Field, notes that sauropod dinosaurs (the big plant-eaters with the long necks) used to be thought of as giraffelike beasts that held their necks upright. In fact, Kissel reports, recent computerized reconstructions suggest they held their necks horizontally, flexing them downward to feed.

The second exhibition to complement one of our features is “Imperial Rome,” on display from now through August 12 at the Houston Museum of Natural Science. Readers with a weakness for archaeology, geology, or history will find that Marie D. Jackson’s article about the stone that built ancient Rome (“Vulcan’s Masonry,” page 40) offers a fascinating counterpoint to the Houston exhibition, and a glimpse into the genius of ancient Roman stonemasons.

—PETER BROWN

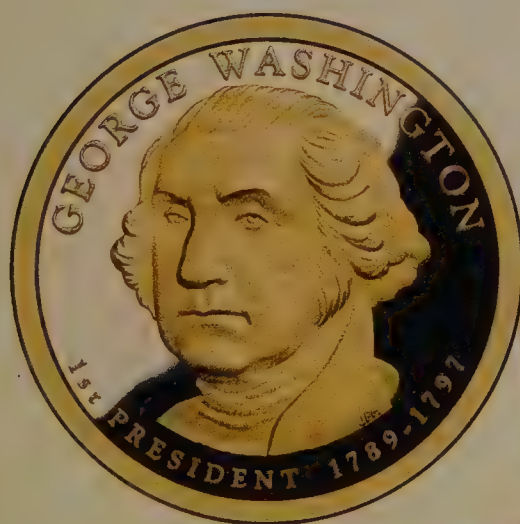


You collected the states. Now hail the chiefs.

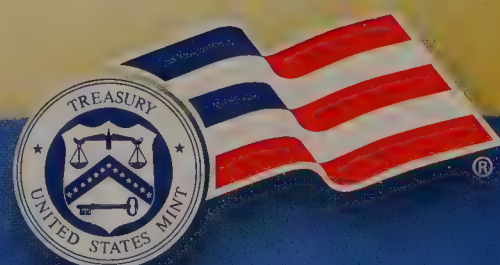
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The photographer **SATOSHI KURIBAYASHI** ("The Natural Moment," page 4) has spent the past thirty-eight years making extreme close-ups—mostly of insects—with camera equipment he specially modifies for the job. On two occasions the Photographic Society of Japan has named him photographer of the year, and in fall 2006 he won the Lennart Nilsson Award for scientific photography. Kuribayashi's most recent book is *In Front of the Ant* (Kane/Miller). More of his microlandscapes can be seen at his Web site (www5.ocn.ne.jp/~kuriken).



Originally from Australia, **LYNDA L. SHARPE** ("Meerkats At Play," page 28) joined the Kalaahari Meerkat Project of the University of Cambridge in 1996. She spent eight years in the desert in South Africa studying the social behavior of meerkats, earning a doctorate from the University of Stellenbosch in Matieland, South Africa. Flower, one of the pups Sharpe followed from birth to adulthood, is the dominant female of the Whiskers meerkat group, now starring in the Animal Planet television series *Meerkat Manor*. Before her work with meerkats, Sharpe was at Monash University in Australia, where she studied play behavior in the puppies of captive African wild dogs and in carnivorous marsupials. She is doing postdoctoral research on sentinel behavior in dwarf mongooses at the University of Stellenbosch.

RICHARD A. KISSEL ("The Sauropod Chronicles," page 34) thanks his dad for frequent trips to the great dinosaur hall at the Carnegie Museum of Natural History in Pittsburgh, where mounts of *Apatosaurus*, *Diplodocus*, and *Tyrannosaurus* fueled his interest in all things extinct. Today, as a paleontologist who has studied dinosaurs and other ancient creatures, he has been delving more deeply into the history of his profession. Kissel is science program developer for the Field Museum in Chicago, where he is responsible for designing, coordinating, and teaching programs on paleontology and other science-based topics. He served as the primary scientific adviser for "Evolving Planet," the museum's new, 27,000-square-foot exhibition on the history of life on Earth.



During a year spent in Rome with her family, geologist **MARIE D. JACKSON** ("Vulcan's Masonry," page 40) became fascinated with the diversity of volcanic rock that forms the foundation of ancient Roman stone architecture. Her collaborations with Italian and American investigators have led to a new analysis of the building materials used by Roman stonemasons, which the Roman architect Vitruvius described in the late first century B.C. The research she presents in this article was published in the three scholarly journals *Archaeometry*, *Journal of the Construction History Society*, and *American Journal of Archaeology*. Her research focus has now turned to examining ancient Roman concretes. Jackson teaches at Northern Arizona University in Flagstaff.

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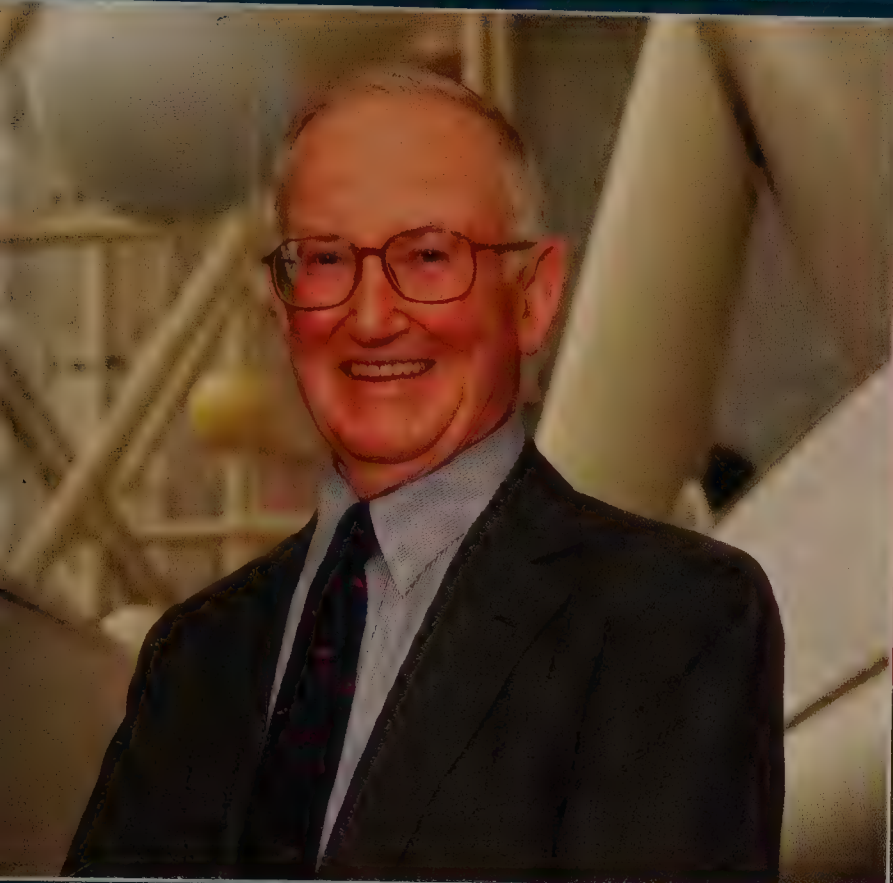
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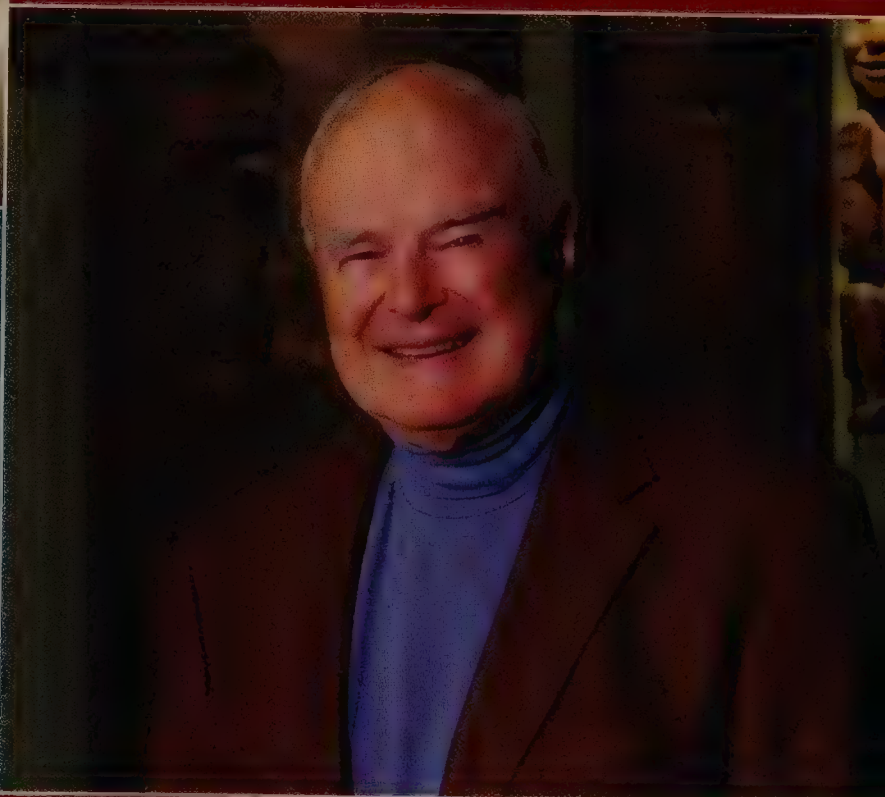


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—Donald K. Clifford, Jr.

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—John C. Bierwirth



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LETTERS

Blowing Hot and Cold

I am befuddled that Donald Goldsmith ["Ice Cycles," 3/07] finds it "sad" that "the present release of carbon dioxide, mainly through the burning of coal and oil, overcompensates for any cooling trend by several orders of magnitude." Why not conclude, instead, that it is possible that human activities that cause global warming may have saved us all from the onset of the next catastrophic ice age?

*John D. Marshall
Beaverton, Oregon*

Donald Goldsmith cites the analogy between Milutin Milankovitch's hypotheses and the long period before the acceptance of Alfred L. Wegener's continental-

drift theory. Milankovitch actually published his theory much earlier than his 1941 book, which Mr. Goldsmith cites, and also collaborated with Wegener on the geologic evidence. Wegener's 1925 paper (with Eduard Brückner and Wladimir Köppen), "The Climates of the Distant Geological Past," includes a "radiation curve" by Milankovitch that matched four alpine ice ages.

Wegener asked Milankovitch to extend his research "to find out what the mechanical cause of polar wandering could be." But Wegener died in 1930, before their collaboration could continue.

*Matt Brzostowski
Houston, Texas*

DONALD GOLDSMITH REPLIES: John D. Marshall suggests that the release of carbon dioxide has saved us from an ice age. But because ice ages come on slowly, we would have plenty of time to plan a limited release of carbon dioxide to counteract any cooling trend. Our present behavior has no such motivation; it results instead from our refusal to consider the planetary impact of continuing to increase our burning of fossil fuels. One should not fight a cold snap by setting fire to one's house.

Octopus Eyes

I have a small correction to a caption that accompanies Jennifer A. Mather's article on octopuses ["Eight Arms,

With Attitude," 2/07]. The eye of the octopus is described as having a cornea. In fact, the pupil is open to seawater, which is interesting in itself.

I also have a question: Octopuses have only one visual pigment in the photoreceptors of the retina. Because at least two visual pigments are required for color vision, how can the octopus change its color and even its texture in response to its environment, without being able to see whether its changes match or contrast with the background?

*Ivan R. Schwab, M.D.
University of California,
Davis
School of Medicine
Sacramento, California*



essential, th
POLICE 2

JENNIFER A. MATHER REPLIES: Ivan R. Schwab is right about the lack of a cornea; I did not compose the original caption, and the error slipped by.

How a color-blind animal can match background colors is a question that has fascinated those who study cephalopods. First, cephalopods can match background contrast, and they do it well. Second, the reflective layers of iridophores and leucophores (which lie beneath the chromatophore pigment sacs) tend to reflect ambient light and thus match background color to a fair extent. Third, pattern generators ensure that the animal matches the visual texture of its environment. Finally, not all conceal-

ment involves background matching; some is disruptive instead. H.B. Cott's classic 1940 book, *Adaptive Coloration in Animals*, is instructive on the general principles.

Spinmeister

Charles Liu's assertion, in his article "Spin Control" [3/07], that engineers design pipeline systems "with Reynolds numbers no higher than about 2,000," is not correct. True, a Reynolds number of about 2,300 is the transition point between laminar and turbulent flow. But except in unusual cases, an engineer would design a pipeline for a Reynolds number much greater than 2,300. Turbulent flow leads to less

drag between the fluid and the wall of the pipe, and so less energy per pound of fluid is needed to move that fluid along the pipe. —

Roderick A. Dibble
Chagrin Falls, Ohio

CHARLES LIU REPLIES: I thank Roderick A. Dibble for sharing his expertise. To be accurate, my text should read: "... with Reynolds numbers lower than about 2,000 to ensure laminar flow, and higher than about 3,000 to ensure turbulent flow."

Just as pipeline systems are strongly influenced by their boundary conditions—such as the contact between the pipe walls and the fluid—so, too, are astrophysical systems. In my

view, that's why the result I reported was so significant.

Overactive Volcano

Contrary to what Robert Anderson states in his column "New Tubes" [3/07], Mount St. Helens is in Washington State. The volcano is still active, but not active enough to have moved to Oregon.

Ann Bjork
Seattle, Washington

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SAMPLINGS

Space Bling

Carbonado diamonds, also called black diamonds, are nothing like their flashy cousins: they're an opaque black or gray, with a porous, sometimes charcoal-like texture. Conventional diamonds, moreover, form under pressure deep within the Earth and are shot toward the surface in hot, volcanic pipes, whereas the origin of carbonados has remained as dark as their color. They're found only in the Central African Republic and Brazil, and even there, they never occur in volcanic formations. A new study has finally illuminated the mystery, showing that carbonados came not from far below, but from far above—from outer space.

Jozsef Garai and his former graduate adviser, Stephen E. Haggerty, a geoscientist at Florida International University in Miami, along with two colleagues, analyzed the chemical bonds in carbonados by studying how they absorb infrared light. The technique, commonly employed with conventional

diamonds, had been impossible to apply to carbonados because of silica impurities that mask absorption of relevant wavelengths of infrared light. The team devised a way to remove the impurities from crushed carbonados, then made the standard infrared analysis. They also aimed a much brighter infrared beam at impurity-free areas of carbonado slices. The result was the first complete infrared analysis of the carbonado diamond.

The study revealed the presence of hydrogen—a sign that the carbonados formed in a hydrogen-rich environment, such as outer space—and a lack of nitrogen clumps, which form only under pressure, deep in the Earth. Those features, along with others, indicate an extraterrestrial origin, possibly in a supernova explosion. Garai and Haggerty say carbonados probably landed on Earth some 3 billion years ago, perhaps as a single, mile-wide asteroid that broke apart before landing. Now that would have been a lot of carats. (*Astrophysical Journal*)

—Stéphan Reeb

Fishy Logic

"Pick your battles wisely" is sound advice that people forget all too often. We could learn a thing or two from *Astatotilapia burtoni*, a little cichlid fish from the shallows of Lake Tanganyika in central Africa. New research shows that *A. burtoni* possesses

surprising powers of logic—for a fish. The males can deduce the pecking order among their rivals after watching only some of them fight each other.

Logan Grosenick and his adviser, Russell D. Fernald, a biologist at Stanford University, along with a colleague, placed "bystander" fish in the central part of an experimental tank. There the bystanders could watch staged, one-on-one fights between five rival males in compartments around the tank's perimeter. To establish a dominance hierarchy among the rivals, the investigators predetermined the outcome of each fight by handicapping one contender—removing it from the water to stress it, then placing it in the other's home tank. Only closely ranked rivals were pitted

Grow Long

In a colony of naked mole rats, as in a beehive, only one female—the queen—gets to breed. A mole-rat queen is easy to recognize because her body is the longest one in the colony. Furthermore, once she dies, the other females fight to replace her, and the victor grows longer with time. What's causing all the stretching?

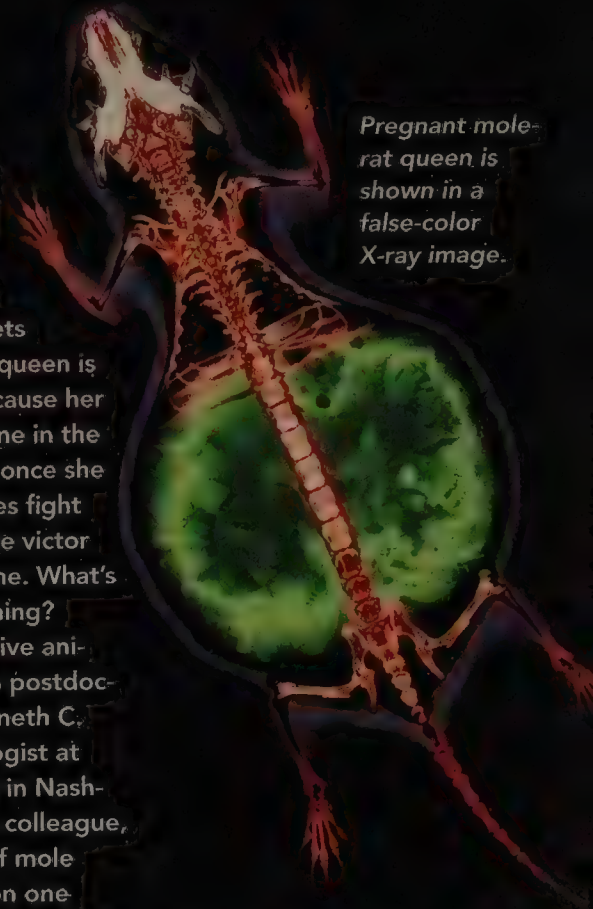
Working with captive animals, Erin C. Henry, a postdoctoral fellow, and Kenneth C. Catania, a neurobiologist at Vanderbilt University in Nashville, together with a colleague, took weekly X rays of mole rats. Concentrating on one representative vertebra, they measured the length of the fourth lumbar in "new queens" (females recently paired with a mate) and in a mole-rat bachelorette over a period of two and a half years.

Among the queens that underwent five or more pregnancies during the study period, the lengths of the fourth lumbar increased, on average, by 34 percent; in the bachelorette, the increase was less than 14 percent. Thus a longer body is probably a consequence of pregnancy. Most of the growth in the queens took place during the second half of each pregnancy, when gestation hormones peaked, suggest-

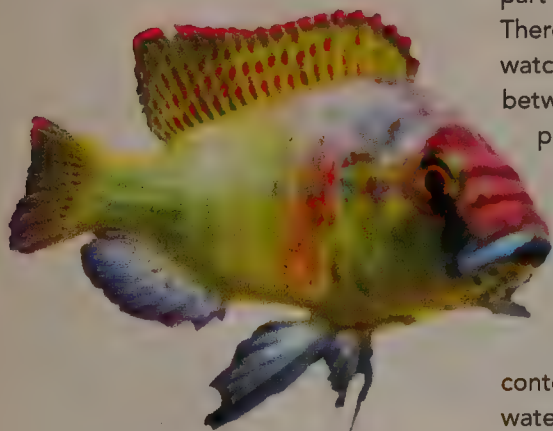
ing that the hormones induce the growth spurts [see "Job Growth," 12/04–1/05].

The average litter of naked mole rats numbers twelve pups, but it can reach twenty-eight, the largest known for any mammal. Sure, it takes a big belly to accommodate that many fetuses, but why grow long, not wide? According to the investigators, queens must remain slim enough to patrol the narrow, subterranean tunnels of their colonies, in part to prevent other females from breeding. Mole-rat moms must literally go to great lengths for their babies. (*Journal of Experimental Biology*)

—S.R.



Pregnant mole-rat queen is shown in a false-color X-ray image.



Astatotilapia burtoni: one smart fish

against one another. Thus the bystanders watched fish A fight and beat fish B, B fight and beat C, and so on through fish E.

After exposing eight bystanders to either two or four of the fights each day for eleven days, the investigators tested whether the bystanders had been able to infer the complete hierarchy despite the gaps in their knowledge. Each bystander was shown two males that had never fought—A and E or B and D—in compart-

ments on opposite sides of the tank. In nearly all the trials, the bystander clearly identified the lower ranking of the two males, visiting him first and spending longer near him (a sensible preference, considering a bystander's improved odds at beating a low-ranking rival). That cognitive leap is roughly equivalent to the reasoning abilities children attain around age four. Not bad for a fish! (*Nature*)

—Nick W. Atkinson



Cold Wind from the East

During the most recent ice age, some 20,000 years ago, a thick ice sheet covered Canada and parts of the northern United States. The climate then was obviously quite different than it is today—but was it so different that the prevailing winds south of the ice sheet blew in a different direction? Xiaohong Feng, an earth scientist at Dartmouth College in Hanover, New Hampshire, and several colleagues came up with a clever way to answer that question.

Feng's team analyzed pieces of ancient wood collected across the continent for two rare, heavy isotopes of the elements that make up water, deuterium (hydrogen-2) and oxygen-18. The isotopes came from the rainwater taken up by the trees when they were alive. Because rainwater molecules made of heavy isotopes fall to Earth before those made of light isotopes do, the higher the proportion of heavy isotopes in the ancient wood, the closer the rain clouds were to their origin, the ocean.

The investigators discovered that the relative amounts of deuterium and oxygen-18 in North American wood from the most recent ice age decline from east to west. Hence the winds prevailing across the continent blew from the east. After the ice age, beginning about 10,000 years ago, the wood shows a different pattern: the levels of the two isotopes reach minimum in the Midwest and rise toward both coasts, the mark of modern prevailing westerlies and the storms that take place on both coasts. (*Geology*)

—S.R.

Reading the Leaves

There's nothing corny about global warming, perhaps the twenty-first century's most serious environmental and economic challenge. But a new study shows that corn can help map emissions of carbon dioxide (CO₂), an important greenhouse gas.

CO₂ released by burning fossil fuels includes much less of the isotope carbon-14 than does naturally occurring CO₂. Furthermore, plants incorporate carbon from atmospheric CO₂ into their greenery during photosynthesis. So Diana Y. Hsueh and her adviser, James T. Randerson, an earth scientist at the University of California, Irvine, and colleagues argue that plants provide a cost-effective means of sampling the

Early Adapters

Some plants take decades to mature before reproducing; others complete their entire life cycles in a year. A new study shows that when it comes to global warming, fast-maturing plants might have a "leaf up" on slow-maturing plants because they can evolve quickly in response to climate variations.

Steven J. Franks, an evolutionary biologist at the University of California, Irvine, and two colleagues studied field mustard



Field mustard



CO₂ sampler: no assembly required

CO₂ derived from fossil fuels. And what better plant for that job in North America than abundant, ubiquitous corn?

Hsueh and Randerson's team analyzed the carbon-14 in corn leaves gathered from sixty-seven locations across the United States and Canada, then made a map of North American CO₂ emissions derived from fossil fuels. What they discovered was hardly surprising: plenty of emissions in

California and the eastern U.S. (the Ohio Valley in particular), both densely populated regions, and relatively few in the less-populous Rocky Mountains and the Great Plains. The agreement with known patterns of fossil-fuel use shows the technique is a reliable mapping tool that could help track emissions over time and pinpoint high-level sources. (*Geophysical Research Letters*)

—S.R.

(*Brassica rapa*), a weedy annual plant common throughout North America. The team collected field-mustard seeds from two sites in California in 1997, after several years of heavy rainfall, and again in 2004, after a five-year drought. They grew plants from the seeds, then experimentally subjected the plants' offspring to dry, moist, or wet growing conditions. Members of the postdrought lineage were clearly adapted to a parched environment: under dry conditions they had a higher survival rate than predrought-lineage members, and under all three growing conditions they flowered earlier. (During a drought, early flowering gives plants a better chance of reproducing before they wither.)

Franks's team then crossed pre- and postdrought plants, and grew the hybrid offspring

alongside other pre- and post-drought plants. Sure enough, the timing of the hybrids' flowering was intermediate, confirming that flowering time is hereditary and changes with selective pressure from drought. In short, the field-mustard populations had evolved.

Franks did not test the adaptive responses of slow-maturing plants, which include many species of trees. Nevertheless, he reasons, the demonstrated adaptability of fast-maturing plants, such as field mustard, to climate variability gives them an advantage over slow-maturing plants, which simply have fewer generations, hence fewer chances to adapt, in a given time. Of course, Franks warns, if climate change becomes extreme, even the weeds won't evolve fast enough to keep up. (*PNAS*)

—Rebecca Kessler

SAMPLINGS

What Killed Napoléon?

Had Napoléon Bonaparte escaped or been released from his exile on the South Atlantic island of Saint Helena, some historians believe, European history might have taken a decidedly different course. But a recent investigation into the cause of the former emperor's death there in 1821, at age fifty-two, suggests otherwise.

The autopsy report for Napoléon listed stomach cancer as the cause of death. But in 1961 investigators discovered elevated levels of arsenic in his hair, spurring theories that he had been poisoned, perhaps by his supposed friend, the Comte de Montholon. Moreover, accounts of Napoléon's obesity in his later years seemed to refute the stomach-cancer hypothesis.

In a recent study, a team led by two pathologists—Alessandro Lugli of University Hospital of Basel in Switzerland and Robert M. Genta of the University of Texas South-

western Medical Center in Dallas—took another look at the emperor's death. They evaluated his clinical history and autopsy reports, his physician's memoirs, and other pertinent historical documents in accord with the methods of modern pathology. They also compared his case to 135 recent confirmed cases of stomach cancer. Their conclusion: Napoléon had an advanced, debilitating stomach cancer that would have prevented him from altering the balance of European power had he left Saint Helena.

The team found no evidence that arsenic poisoning caused Napoléon's death (though



Paul Delaroche, Napoléon at Fontainebleau, March 31, 1814, 1840 (detail)

was infected with the bacterium *Helicobacter pylori*, which could have caused an ulcer and ultimately led to his fatal cancer. (*Nature Clinical Practice Gastroenterology & Hepatology*)

—Graciela Flores

The Carnivore's Dilemma

Land mammals that eat meat fall into two camps: the kiddie-menu crowd and the supersize-me set. Small carnivores usually go after bite-size prey, such as worms and mice, which don't take much effort to hunt. But even the most proficient hunter can catch only

A new model developed by Chris Carbone, a biologist at the Zoological Society of London, and two colleagues explains how the balance between gains and expenditures in energy determines—and limits—the carnivores' size and their prey selection. According to the model, as body size surpasses forty pounds, the metabolic costs of hunting rise more steeply than the energy gained. A carnivorous mammal weighing more than about a ton couldn't catch enough prey—no matter how large—to survive.

That's a good fit with reality: the larg-

est known mammalian predators, such as the extinct short-faced bear, max out at around a ton. Those and even somewhat smaller meat-eaters probably live close to the edge in maintaining their delicate energy balance. Indeed, they have advanced energy-conservation tactics, such as lions' long bouts of inactivity



Short-faced bear, now extinct

so many small prey a day. As species get bigger, the energy gained from catching small prey soon lags behind rising metabolic needs and hunting costs. For carnivores weighing more than about forty pounds, the size of a coyote, it pays to switch to large prey, so large carnivores hunt animals closer to their own size.

Ménage à Trois

Hot geothermal soils aren't particularly hospitable to plant life, yet that's where *Dichanthelium lanuginosum*, a species of grass, thrives. It owes its survival to a symbiotic fungus, *Curvularia protuberata*, that lives in its tissues—or so plant biologists thought. But new research has uncovered a third party to the affair: a virus.

Grown separately, neither the grass nor the fungus survives temperatures above 100 degrees Fahrenheit; when grown together, the two do just fine at a sweltering 149 degrees. But the fungus, it turns out, is protective only when a virus is infecting its tissues. The discovery was made by Luis M. Márquez, an ecologist, and Marilyn J. Roossinck, a viral

or bears' hibernation. Carbone thinks that explains why more large carnivores run a bigger risk of extinction than small carnivores or vegetarians: they're more vulnerable to changes in the availability of prey. As nature's self-appointed custodians, we should take note. (*PLoS Biology*)

—S.R.

evolutionary ecologist, both at the Samuel Roberts Noble Foundation in Ardmore, Oklahoma, along with two colleagues.

Grasses inoculated with a virus-free form of the fungus acted just like grasses that were entirely fungus-free: when grown in soil warmed daily to 149 degrees, they became shriveled and pale, and eventually died. Then, to confirm that the virus was responsible for the increased thermal tolerance, the investigators reintroduced the virus into the virus-free fungus. Sure enough, the newly infected fungus conferred the same level of heat tolerance in the grass as the naturally infected fungus did. Moreover, the infected fungus had a similar protective effect when transferred to the tomato plant, *Solanum lycopersicon*. Tomato is only distantly related to grass, suggesting that the virus affects a physiological mechanism for heat tolerance common to many plants.

All plants harbor fungal symbionts, some of which carry viruses, but this example is the first known case of a virus, a fungus, and a plant living together cooperatively. Others surely remain to be discovered. (*Science*) —G.F.

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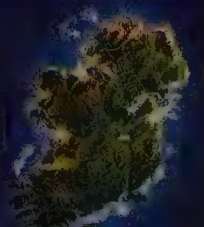


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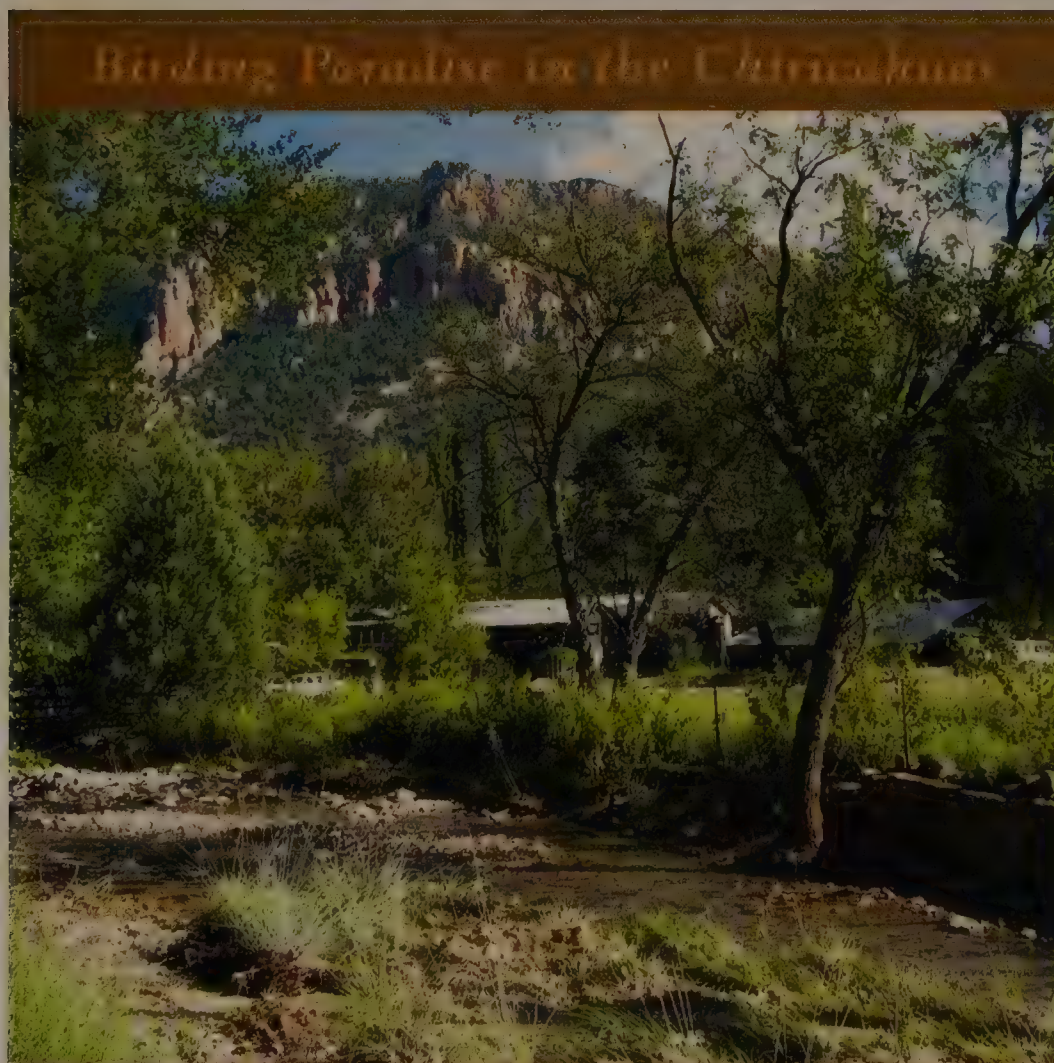
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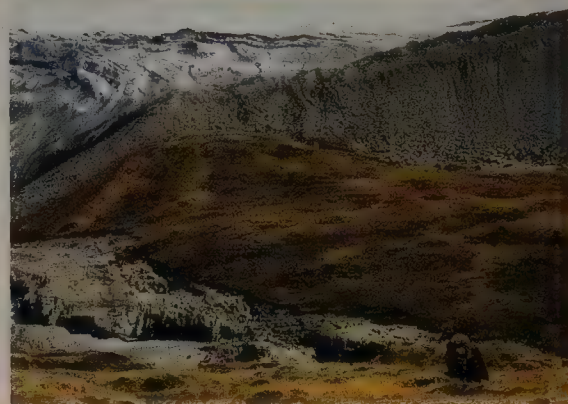
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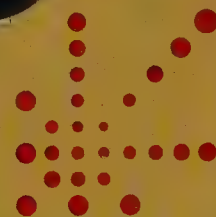


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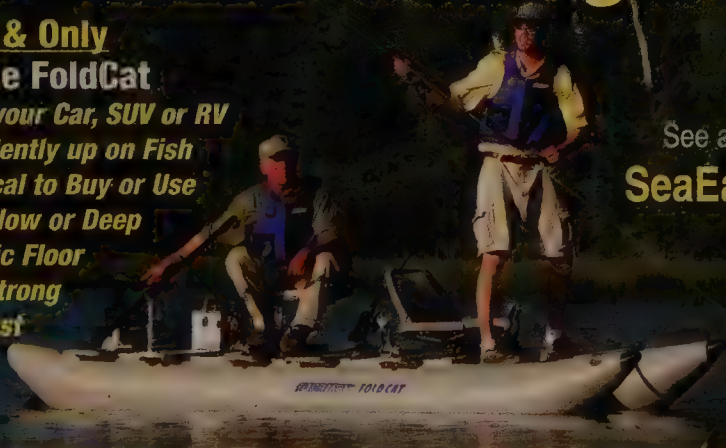
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The Cosmic Perspective

For this month's special anniversary of his "Universe" column, Neil deGrasse Tyson explains how embracing cosmic realities can give us a more enlightened view of human life.

By Neil deGrasse Tyson

Of all the sciences cultivated by mankind, Astronomy is acknowledged to be, and undoubtedly is, the most sublime, the most interesting, and the most useful. For, by knowledge derived from this science, not only the bulk of the Earth is discovered, but our very faculties are enlarged with the grandeur of the ideas it conveys, our minds exalted above [their] low contracted prejudices.

—James Ferguson, *Astronomy Explained Upon Sir Isaac Newton's Principles, And Made Easy To Those Who Have Not Studied Mathematics* (1757)

Long before anyone knew that the universe had a beginning, before we knew that the nearest large galaxy lies two and a half million light-years from Earth, before we knew how stars work or whether atoms exist, James Ferguson's enthusiastic introduction to his favorite science rang true. Yet his words, apart from their eighteenth-century flourish, could have been written yesterday.

But who gets to think that way? Who gets to celebrate this cosmic view of life? Not the migrant farmworker. Not the sweatshop worker. Certainly not the homeless person rummaging through the trash for food. You need the luxury of time not spent on mere survival. You need to live in a nation whose government values the

search to understand humanity's place in the universe. You need a society in which intellectual pursuit can take you to the frontiers of discovery, and in which news of your discoveries can be routinely disseminated. By those measures, most citizens of industrialized nations do quite well.

Yet the cosmic view comes with a hidden cost. When I travel thousands of miles to spend a few moments in the fast-moving shadow of the Moon during a total solar eclipse, sometimes I lose sight of Earth.

When I pause and reflect on our expanding universe, with its galaxies hurtling away from one another, embedded within the ever-stretching, four-dimensional fabric of space and time, sometimes I forget that uncounted people walk this Earth without food or shelter, and that children are disproportionately represented among them.

When I pore over the data that establish the mysterious presence of dark matter and dark energy throughout the universe, sometimes I forget that every day—every twenty-four-hour rotation of Earth—people kill and get killed in the name of someone else's conception of God, and that some people who do not kill in the name of God

kill in the name of their nation's needs or wants.

When I track the orbits of asteroids, comets, and planets, each one a pirouetting dancer in a cosmic ballet choreographed by the forces of gravity, sometimes I forget that too many people act in wanton disregard for the delicate interplay of Earth's atmosphere, oceans, and land, with consequences that our children and our children's children will witness and pay for with their health and well-being.

And sometimes I forget that powerful people rarely do all they can to help those who cannot help themselves.

I occasionally forget those things because, however big the world is—in our hearts, our minds, and our outsize atlases—the universe is even bigger. A depressing thought to some, but a liberating thought to me.

Consider an adult who tends to the traumas of a child: a broken toy, a scraped knee, a schoolyard bully. Adults know that kids have no clue what constitutes a genuine problem, because inexperience greatly limits their childhood perspective.

As grown-ups, dare we admit to ourselves that we, too, have a collective immaturity of view? Dare we admit that our thoughts and behaviors spring from a belief that the world revolves around us? Apparently not. And the evidence abounds. Part the curtains of society's racial, ethnic, religious, national, and cultural conflicts, and you find the human ego turning the knobs and pulling the levers.

Now imagine a world in which everyone, but especially people with power and influence, holds an expanded view of our place in the cosmos. With that perspective, our problems would shrink—or never arise at all—and we could celebrate our earthly differences while shunning the behavior of our predecessors who slaughtered each other because of them.

Back in February 2000, the newly rebuilt Hayden Planetarium featured a space show called "Passport to the Universe," which took visitors on a virtual zoom from New York City to the edge of the cosmos. En route the audience saw Earth, then the solar system, then the 100 billion stars of the Milky Way galaxy shrink to barely visible dots on the planetarium dome.

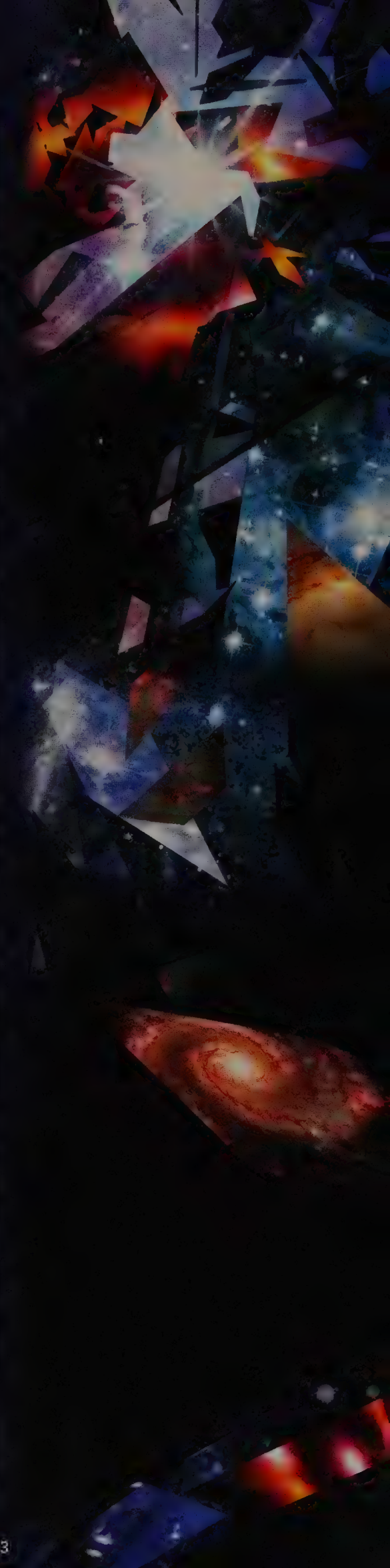
Within a month of opening day, I received a letter from an Ivy League professor of psychology whose expertise was things that make people feel insignificant. I never knew one could specialize in such a field. The guy wanted to administer a before-and-after questionnaire to visitors, assessing the depth of their depression after viewing the show. "Passport to the Universe," he wrote, elicited the most dramatic feelings of smallness he had ever experienced.

How could that be? Every time I see the space show (and others we've produced), I feel alive and spirited and connected. I also feel large, knowing that the goings-on within the three-pound human brain are what enabled us to figure out our place in the universe.

Allow me to suggest that it's the professor, not I, who has misread nature. His ego was too big to begin with, inflated by delusions of significance and fed by cultural assumptions that human beings are more important than everything else in the universe.

In all fairness to the fellow, powerful forces in society leave most of us susceptible. As was I until the day I learned in biology class that more bacteria live and work in one centimeter of my colon than the number of people who have ever existed in the world. That kind of information makes you think twice about who—or what—is actually in charge.

From that day on, I began to think of people not as the masters of space and time but as participants in a great cosmic chain of being, with a direct



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genetic link across species both living and extinct, extending back nearly 4 billion years to the earliest single-celled organisms on Earth.

I know what you're thinking: we're smarter than bacteria.

No doubt about it, we're smarter than every other living creature that ever walked, crawled, or slithered on Earth. But how smart is that? We cook our food. We compose poetry and music. We do art and science. We're good at math. Even if you're bad at math, you're probably much better at it than the smartest chimpanzee, whose genetic identity varies in only trifling ways from ours. Try as they might, primatologists will never get a chimpanzee to learn the multiplication table or do long division.

If small genetic differences between us and our fellow apes account for our vast difference in intelligence, maybe that difference in intelligence is not so vast after all.

Imagine a life-form whose brain-power is to ours as ours is to a chimpanzee's. To such a species our highest mental achievements would be trivial. Their toddlers, instead of learning their ABCs on *Sesame Street*, would learn multivariable calculus on *Boolean Boulevard*. Our most complex theorems, our deepest philosophies, the cherished works of our most creative artists, would be projects their schoolkids bring home for Mom and Dad to display on the refrigerator door. These creatures would study Stephen Hawking (who occupies the same endowed professorship once held by Newton at the University of Cambridge) because he's slightly more clever than other humans, owing to his ability to do theoretical astrophysics and other rudimentary calculations in his head.

If a huge genetic gap separated us from our closest relative in the animal kingdom, we could justifiably celebrate our brilliance. We might be entitled to walk around thinking we're distant and distinct from our fellow creatures. But no such gap exists. Instead, we are one

with the rest of nature, fitting neither above nor below, but within.

Need more ego softeners? Simple comparisons of quantity, size, and scale do the job well.

Take water. It's simple, common, and vital. There are more molecules of water in an eight-ounce cup of the stuff than there are cups of water in all the world's oceans. Every cup that passes through a single person and eventually rejoins the world's water supply holds enough molecules to mix 1,500 of them into every other cup of water in the world. No way around it: some of the water you just drank passed through the kidneys of Socrates, Genghis Khan, and Joan of Arc.

How about air? Also vital. A single breathful draws in more air molecules than there are breathfuls of air in Earth's entire atmosphere. That means some of the air you just breathed passed through the lungs of Napoleon, Beethoven, Lincoln, and Billy the Kid.

Time to get cosmic. There are more stars in the universe than grains of sand on any beach, more stars than seconds have passed since Earth formed, more stars than words and sounds ever uttered by all the humans who ever lived.

Want a sweeping view of the past? Our unfolding cosmic perspective takes you there. Light takes time to reach Earth's observatories from the depths of space, and so you see objects and phenomena not as they are but as they once were. That means the universe acts like a giant time machine: the farther away you look, the further back in time you see—back almost to the beginning of time itself. Within that horizon of reckoning, cosmic evolution unfolds continuously, in full view.

Want to know what we're made of? Again, the cosmic perspective offers a bigger answer than you might expect. The chemical elements of the universe are forged in the fires of high-mass stars that end their lives in stupendous explosions, enriching their host galaxies with the chemical arsenal of life as we know it. The result? The four most common chemically active elements

in the universe—hydrogen, oxygen, carbon, and nitrogen—are the four most common elements of life on Earth. We are not simply in the universe. The universe is in us.

Yes, we are stardust. But we may not be of this Earth. Several separate lines of research, when considered together, have forced investigators to reassess who we think we are and where we think we came from.

First, computer simulations show that when a large asteroid strikes a planet, the surrounding areas can recoil from the impact energy, catapulting rocks into space. From there, they can travel to—and land on—other planetary surfaces. Second, microorganisms can be hardy. Some survive the extremes of temperature, pressure, and radiation inherent in space travel. If the rocky flotsam from an impact hails from a planet with life, microscopic fauna could have stowed away in the rocks' nooks and crannies. Third, recent evi-

dence suggests that shortly after the formation of our solar system, Mars was wet, and perhaps fertile, even before Earth was.

Those findings mean it's conceivable that life began on Mars and later seeded life on Earth, a process known as panspermia. So all earthlings might—just might—be descendants of Martians.

Again and again across the centuries, cosmic discoveries have demoted our self-image. Earth was once assumed to be astronomically unique, until astronomers learned that Earth is just another planet orbiting the Sun. Then we presumed the Sun was unique, until we learned that the countless stars of the night sky are suns themselves. Then we presumed our galaxy, the Milky Way, was the entire known universe, until we established that the countless fuzzy things in the sky are other galaxies, dotting the landscape of our known universe.

Today, how easy it is to presume that one universe is all there is. Yet

emerging theories of modern cosmology, as well as the continually reaffirmed improbability that anything is unique, require that we remain open to the latest assault on our plea for distinctiveness: multiple universes, otherwise known as the "multiverse," in which ours is just one of countless bubbles bursting forth from the fabric of the cosmos.

The cosmic perspective flows from fundamental knowledge. But it's more than just what you know. It's also about having the wisdom and insight to apply that knowledge to assessing our place in the universe. And its attributes are clear:

The cosmic perspective comes from the frontiers of science, yet it is not solely the provenance of the scientist. It belongs to everyone.

The cosmic perspective is humble.

The cosmic perspective is spiritual—even redemptive—but not religious.

The cosmic perspective enables us to

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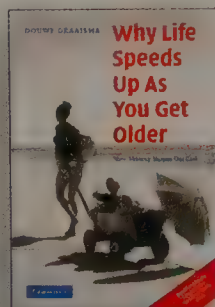


A Generation at Risk

Geoff Foster, Carol Levine, and John G. Williamson, Editors

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- Journal of the American Medical Association



Why Life Speeds Up As You Get Older

How Memory Shapes our Past

Douwe Draaisma, Translated by Arnold Pomerans and Erica Pomerans

"Draaisma...is a terrific writer, whose erudition and passion for the topic are apparent in every page."

- Nature

"Douwe Draaisma's Why Life Speeds Up As You Get Older won prizes when it appeared in Dutch, and is a treasure. The result is informative, amusing and moving. Long after you close it, it leaves a good memory."

- New Scientist

grasp, in the same thought, the large and the small.

The cosmic perspective opens our minds to extraordinary ideas but does not leave them so open that our brains spill out, making us susceptible to believing anything we're told.

The cosmic perspective opens our eyes to the universe, not as a benevolent cradle designed to nurture life but as a cold, lonely, hazardous place.

The cosmic perspective shows Earth to be a mote, but a precious mote and, for the moment, the only home we have.

The cosmic perspective finds beauty in the images of planets, moons, stars, and nebulae but also celebrates the laws of physics that shape them.

The cosmic perspective enables us to see beyond our circumstances, allowing us to transcend the primal search for food, shelter, and sex.

The cosmic perspective reminds us that in space, where there is no air, a flag will not wave—an indication

that perhaps flag waving and space exploration do not mix.

The cosmic perspective not only embraces our genetic kinship with all life on Earth but also values our chemical kinship with any yet-to-be discovered life in the universe, as well as our atomic kinship with the universe itself.

At least once a week, if not once a day, we might each ponder what cosmic truths lie undiscovered before us, perhaps awaiting the arrival of a clever thinker, an ingenious experiment, or an innovative space mission to reveal them. We might further ponder how those discoveries may one day transform life on Earth.

Absent such curiosity, we are no different from the provincial farmer who expresses no need to venture beyond the county line, because his forty acres meet all his needs. Yet if all our predecessors had felt that way, the farmer would instead be a cave

dweller, chasing down his dinner with a stick and a rock.

During our brief stay on planet Earth, we owe ourselves and our descendants the opportunity to explore—in part because it's fun to do. But there's a far nobler reason. The day our knowledge of the cosmos ceases to expand, we risk regressing to the childish view that the universe figuratively and literally revolves around us. In that bleak world, arms-bearing, resource-hungry people and nations would be prone to act on their "low contracted prejudices." And that would be the last gasp of human enlightenment—until the rise of a visionary new culture that could once again embrace the cosmic perspective.

Astrophysicist NEIL DEGRASSE TYSON is the Frederick P. Rose Director of New York City's Hayden Planetarium at the American Museum of Natural History. His most recent book, Death by Black Hole: And Other Cosmic Quandaries (W.W. Norton, 2007), is a collection of his favorite Natural History essays from the past dozen years.

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Meerkats At Play

Evolution demands that activities costing a lot of energy provide survival value in return. But what do these rambunctious little mammals gain from having so much fun?

By Lynda L. Sharpe

Photographs by Andrew J. Young

In the cool freshness of dawn, two meerkat pups raced down the dune toward me. Turning suddenly, they reared up on their stumpy hind legs and clasped each other like little sumo wrestlers. Shuffling to and fro, each pup tried to topple the other, each arching its head back to avoid its opponent's snapping teeth. Without warning, Bandit (or so we named him for his extra-large, dark eye patches) lost his footing and tumbled backward in a spray of red sand. As he lay wriggling on his back, paws waving in the air, Imp, a smaller but feisty pup, leapt on top of him, pinned him down, and nipped enthusiastically at any appendage that came within her reach.

The two young meerkats were acting out one of the greatest mysteries in the world of animal behavior. They were playing. And those of us who study that behavior have no idea why.

Unlike virtually every other kind of animal behavior, play seems to serve no purpose. It is easy to see what an individual gains from grooming, or fighting, or nest building. But play? And if play really has no purpose, why do young mammals (including humans) invest so much time and energy in it?

I kept watching as Imp chased Bandit beneath a spiky shrub. The pair darted back and forth, leaping exuberantly as they snapped and parried. It was clear that they were having a high old time. After all, play is fun; it gives pleasure. Isn't that reason enough to do it? The trouble with such reasoning is that play can also have harmful consequences, which could reduce an individual's chances of surviving to reproduce. Unless play provides some compensatory benefits, evolution would have eliminated the tendency to play. So what benefits do individuals get from playing? My own behavior—crouching in the Kalahari Desert of southern Africa surrounded by eighteen meerkats—was part of an attempt to answer that question.

The meerkat, a species of mongoose, is one of the most sociable mammals in nature. The animals live in highly cooperative groups of as many as fifty individuals. Group members all chip in to rear the young and guard against predators. As

Two meerkats wrestle joyfully, tumbling over each other in the Kalahari Desert of southern Africa. Such play-fighting, to which the animals devote around 3 percent of their day, costs a lot of energy. So unless play also confers an adaptive benefit, evolution would have favored meerkats that do not play. Because meerkat groups are known for social harmony, the animals seemed good candidates for investigating whether play leads to better social bonding—less aggression, stronger alliances among individuals, and greater contributions to the group.

I watched “my” group—which had been named Elveera, after the founding individual—a pair of adolescents groomed the ticks from each other’s noses, while the alpha female, Tenuvial, presented a wormlike larva to one of the pups. I could see how meerkats had earned a reputation for altruism and an “all-for-one-and-one-for-all” approach to life.

The Elveera group was one of thirteen such groups being studied by the Kalahari Meerkat Project, established in 1993 by Tim Clutton-Brock, a behavioral ecologist at the University of Cambridge. Thanks to several years of work by Clutton-Brock’s research team (which I joined in 1996), these wild animals had become used to having a person in their midst, and so I could sit among them without disturbing their behavior. To them, I was a harmless prop in the scene. As if to prove the point, Bettik (Imp’s mother) trotted over and scrambled awkwardly up

my arm, her long claws scratching my skin. Using me as a shrub or a stump, she perched precariously on my shoulder to scan the sky for predators, so the rest of the group could nap in safety.

Suddenly Bettik whistled a piercing alarm, startling the other meerkats—and me. She leapt from my shoulder and dashed with the others to the entrance of the group’s burrow. Little Bandit and Imp, however, playing at the foot of the dune slope, had a long way to run. High above, circling in the pale morning sky, a tawny eagle was on the lookout for just such incautious meerkat pups, a perfect example of the potential cost of play. This time, however, Bandit and Imp shot down the burrow, emerging moments later to peep out cautiously from between the forelegs of their elder brother.

Although young meerkats clearly risk predation or injury during play, they incur an even more substantial cost in energy. Our research in the Kalahari has shown that meerkat pups that are bigger than their siblings grow into more efficient foragers, and they are more likely to become dominant within a group and to breed. So why on earth do young meerkats squander energy on play instead of investing it in growth? Surely play must have a function, and I was determined to find out what it was.

The failure of science to determine the function of play has not been for lack of trying. Investigators, particularly in the 1970s and 1980s, have conducted studies across a range of animal species. People assumed that once accurate information was gathered about the mechanics of play, its function would become self-evident. After all, that approach had worked with almost every other behavior observed in animals. But it did not work for play.

What we do know is that the “content” of a youngster’s play reflects what is important to adults of the same species: lion cubs stalk and pounce; antelope fawns gallop and prong. We also know that play is stimulated by novel objects, novel partners, and novel substrates, such as mud or snow. And of course theorists have come up with many hypotheses, suggesting more than thirty possible benefits of play.

For example, play may stimulate the development of the brain, increase cardiovascular fitness, or help regulate the use of energy. Perhaps play in young animals is a way to practice skills they will need in adulthood, such as fighting, mating, or hunting. Perhaps it is an effective way to learn how to recognize kin, evaluate risk, or cope with stressful situations. The pleasure of play might provide the positive reinforcement needed to strengthen social bonds between individuals, thereby reducing ag-



Adult meerkat emerges from its burrow into the morning light. Meerkats older than six months take turns babysitting newborns at the group’s burrow. If play functioned to enhance social bonding, one might expect meerkats that play more to babysit more, since they would be more committed to the group. But that is not the case.



Group play among meerkats often leads to a furry ball of tangled body parts.

gression, enhancing alliances, and improving group cohesion. Unfortunately, none of those theories has been rigorously tested, and there is little evidence to support or refute any of them.

The sun was now well above the horizon, and the meerkats were wide-awake. The entire group began to play vigorously. As a knot of five pups twisted and rolled over my feet, I knew that there could be no crucial, controlled experiment; there was no way I could prevent a meerkat from playing just to see what happened. Even among captive animals, investigators have found it impossible to stop young mammals from playing without so disrupting their lives that any subsequent changes in their behavior are uninterpretable. How, then, could I test theories about play?

Some theories simply do not lend themselves to testing in the field. But for assessing the possible social benefits of play, wild meerkats seem ideal subjects. You see, though meerkats are highly social, they belong to a family known as the Viverridae in which almost all the species are solitary. As the African climate dried out and the forest turned into savanna, the ancestral mongooses, which foraged out in the open by day, became extremely vulnerable to predation. By sticking together and sharing guard duty, mongooses could substantially reduce their risk. In fact, our observations show that large group size in meerkats is associated with higher rates of growth, survival, and fecundity.

Yet before mongooses could take advantage of the benefits of group living, they had to overcome their inherited antipathy toward other members of their own species. So could play be the key? If play could enhance the bonds between individuals, reducing their aggression and encouraging them to stick together, its evolutionary benefits would be unmistakable. And observers would see meerkats fully exploiting play for just that purpose.

To determine whether meerkats at play were strengthening their social bonds, I had to find out how much each individual played, then look at how differences in the frequency of play affected each animal's behavior. If the social-bonding hypothesis was correct, I reasoned, meerkats that play a lot should be more strongly attached to their fellows than meerkats that play rarely. "Bonded" animals, moreover, should be less aggressive and more strongly committed to the group: they should help more often with group activities and delay their own departure from the group as young adults.

I decided to focus on eight meerkat litters, each from a different group—forty-five pups in all—and then follow them throughout their lives. Recording how much the meerkats played proved harder than I had expected. On some days the entire group would play for more than an hour—as was happening this morning at Elveera. On other days, there was no play at all. Also, it was a year of good rains in the Kalahari, so a sea of golden devil thorn flowers made it hard to spot the meerkats as they dove in and out

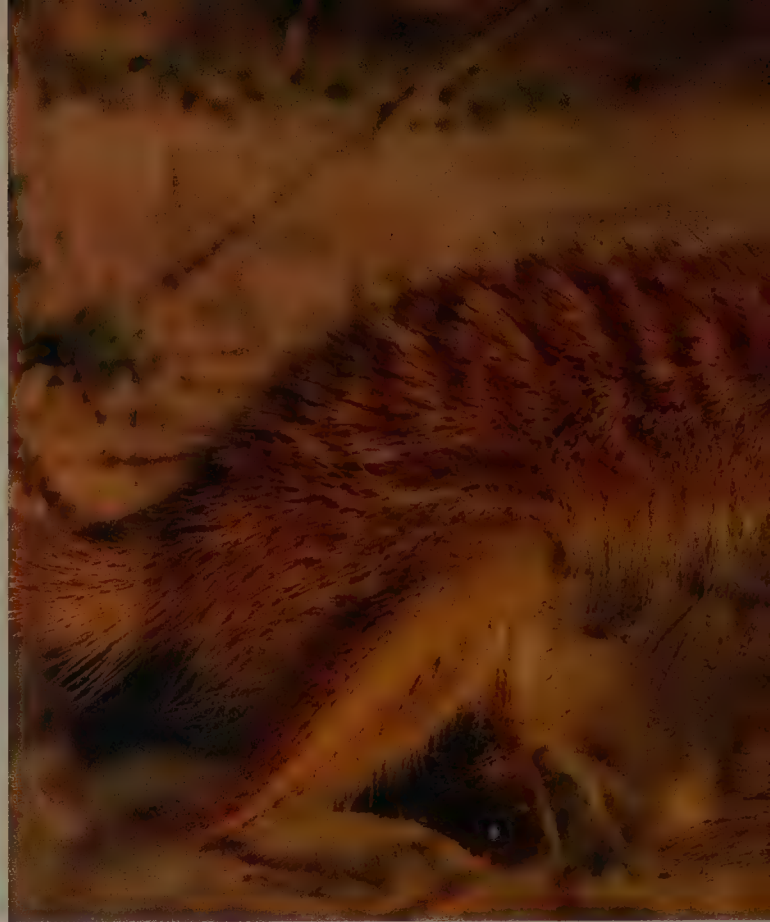
among the blossoms. Worst of all, meerkat play moves so fast that it was almost impossible to see the identifying marks I'd made by trimming small patches of fur or painting dabs of black hair dye on my subjects' bodies. The only body parts that reliably protruded from a scrum of wrestling meerkats were the tails. So each morning, before collecting data, I had to crawl around on my stomach amid the sunning meerkats, clutching an array of multihued marker pens, and surreptitiously draw vibrant rings on the tails of all my study animals.

In spite of the difficulties, I managed to quantify how much each animal played, and found that individual differences were quite large. In the Elveera litter of nine pups, one large, blonde pup called Mimi played twice as often as Bandit or a shy pup named Elf. So one of my questions became, simply: was Mimi less aggressive than Bandit or Elf?

As it happened, there was a good way to quantify aggressive behavior to help answer this question. From four to ten weeks of age, when meerkats learn to find food on their own, each pup must compete for prey items donated by older members of the group. The adults tend to feed whichever pup is closest by, so whenever the group goes foraging, the youngsters fight each other ferociously to get the closest possible position to one or more of the group's most generous feeders. By following each pup in turn, and recording what happened whenever another pup came within a meter of my focal pup, I found I could determine which individuals were most inclined to act aggressively.

Close to my feet, Imp, the smallest pup, was tagging along behind Tenuvial, begging lustily; making an ear-piercing racket actually encourages adults to donate prey items to the pups. Within moments, dark-eyed Bandit launched a fierce attack on Imp. The two pups hurtled toward each other, crashed together, and rolled over and over, squealing, growling, and biting mercilessly. In the end, Bandit emerged victorious to usurp Imp's place beside Tenuvial. Fighting is common among pups of this age, but if the social-bonding theory is correct, the combatants that engage most often in such ghastly struggles would be pairs that rarely share in play. Furthermore, preferred playmates would fight with each other less frequently. So are those predictions correct?

As it turns out, they are not. There was no correlation between how much an individual (or a litter) played and how aggressively it behaved. Blonde Mimi spent twice as much time as Elf did in play, but she launched just as many attacks on her littermates as Elf did. Similarly, preferred playmates such as Bandit and Mimi were just as likely to fight



Meerkat play closely mirrors real fighting, but the author's research shows that play does not improve an individual's fighting skills or its ability to win a real fight for dominance. She also found that meerkats that prefer to play together are not less likely to engage in real fights.

while begging for food as were pups such as Bandit and Elf that rarely shared in play.

Play also had no short-term effect on aggression. Pairs of pups out foraging were just as likely to attack each other within ten minutes of playing together as were pairs of pups that had not just played. And female meerkats that played relatively often with the group's alpha female were just as likely to be bullied and harassed by her (when she was feeling aggressive during late pregnancy) as were females that had not played with the alpha.

Social-bonding theory does not just predict that play reduces aggression; it also maintains that play strengthens an individual's attachment to its playmates, promoting alliances and enhancing group cohesion. Did meerkats that played more often—Mimi and a pinch-faced meerkat named Goblin—subsequently show greater commitment to their group? And did pairs that liked to play together team up later to form special alliances in adulthood?

To begin answering those questions, I recorded how much each of my meerkats contributed to the activities of its group. My working assumption was that the more closely an individual was bonded to its group, the more it would want to contribute to the group. Furthermore, I reasoned, the more closely bonded an individual, the longer it would remain with the group and so the more it stood to



gain from its contributions to group well-being.

Fortunately, it was fairly straightforward to collect data on group contributions. By the time my study animals were three or four months old, they were already dashing about excitedly, helping rear the next generation of pups. I recorded how often each animal donated prey items to the new pups, and on how many days it babysat. Babysitting seemed particularly altruistic: the babysitter had to go without food for the day in order to remain at the breeding burrow with the newborn pups, while the rest of the group went foraging. I also measured how often each meerkat performed sentinel duty, and how often it helped clear debris from the group's sleeping burrows and bolt-holes.

Collecting data on alliances was also relatively straightforward. Meerkats usually remain with their natal group until they are about two years old (despite reaching sexual maturity between seven and eleven months). When the meerkats finally left their natal group, I could note which ones left earliest (the behavior expected of poorly bonded individuals) and which ones formed so-called dispersal alliances (that is, left their natal group together).

So did play strengthen a meerkat's commitment to its group, enhancing group cohesion? No. Mimi, Goblin, and other pups dedicated to play did not end up contributing more to the group than meerkats that played infrequently. In fact, within the Elveera group, Bandit became the most dedicated babysitter despite his relative lack of play. Similarly, individuals that played more frequently than their peers did not delay leaving their group. The highly playful Goblin

left home to join a neighboring group when he was only eleven months old. Bandit, by contrast, stayed in the Elveera group until he was three. Among the females, Mimi, Imp, and two of their sisters left home at twenty months of age to set up their own group with males from another group. In contrast, Elf (the nonplayer) remained behind in Elveera.

What about the role of play in helping individuals establish lifelong alliances, such as dispersal partnerships? Meerkats typically disperse with one or more groupmates of the same sex. Furthermore, dispersing animals in large parties are less stressed, better fed, and more likely to oust competitors than animals that disperse alone or in pairs. Could that be the purpose of meerkat play, to cultivate bonds between potential dispersal partners?

Once again, on scrutiny, the supposed connection disappears. Meerkats that played together most often did not appear to be more closely attached. Frequent playmates did not groom each other any more often than they groomed other group members, and they were just as likely to engage in teenage squabbles over status. Male meerkats were no more likely to team up with their preferred playmates when embarking on short-term forays to neighboring groups to check out the "talent." And as for dispersing, the individuals with which my study animals dispersed were not the ones they had played with most often.

In short, despite all my efforts, I did not find out why meerkats play. What I did show, at least, is that they do not play to strengthen social bonds. And if meerkats aren't using play in that way, it's almost certainly because play is simply not capable of generating the physiological changes needed to reduce aggression or increase social attachment.

Back in the Elveera group, the meerkats finally stopped foraging and withdrew into the tangled shade of a fallen camel thorn tree for their midday siesta. While the adults sprawled on their tummies, legs splayed out to make more contact with the shade-cooled sand, I let myself relax and enjoy the company of my study animals. In the long strip of shade beneath the fallen trunk, the nine pups lay side by side in a neat line. Too tired for their usual exuberant play, they lay on their backs, waving their stumpy legs in the air, and lazily gnawed on their neighbor's ears, nose, and toes. I smiled at their mystery. □

For more information about meerkats, go to www.naturalhistorymag.com and click "Online extras," then "Web links," and finally "April 2007" to find links related to this article.

The Sauropod Chronicles

The largest creatures ever to have walked the Earth were animals such as Apatosaurus—aka Brontosaurus. Paleontologists are revising the picture of how they lived. Again.

By Richard A. Kissel



Paleontological crew (above) at the American Museum of Natural History, ca. 1904, works at mounting *Apatosaurus excelsus* (aka *Brontosaurus excelsus*), the first nearly complete fossil skeleton of a sauropod to be put on public display. An 1891 reconstruction of *B. excelsus* by the Yale paleontologist Othniel Charles Marsh is shown at the top of the page.

In 1842, the English anatomist and pioneering paleontologist Richard Owen introduced the word “dinosaur” to distinguish a new category of reptiles. Today dinosaurs are familiar to people of all ages, and perhaps none are more familiar than the sauropods. They are instantly recognizable for their small heads borne on long, graceful necks; their heavy, sinuous tails; and their enormous bodies, all supported on four stout limbs. So far, paleontologists have unearthed more than 120 species.

The earliest known sauropod appeared about 215 million years ago, during the Late Triassic period, and the last of the kind lived until the end of the Cretaceous period, 65 million years ago—when a worldwide cataclysm wiped out all dinosaurs except the birds. All sauropods were herbivorous, and most of them were massive. The largest ones, such as *Argentinosaurus* of South America, reached more than a hundred feet in length and may have weighed as much as eighty tons. Even a small one, such as *Saltasaurus*, measured more than twenty feet from head to tail, tipping the scales at three tons. Most sported no obvious defenses—the sharp spikes or sheath of bony armor found in other plant-eating dinosaurs—so mass alone may have been their means to intimidate or discourage predators.

Just as intriguing as the sauropods themselves is the story of their discovery and of paleontologists’ efforts to understand their lives. Like all other scientific disciplines, paleontology has a history punctuated by change. Its advances accrue not only from the discovery of new fossils but also from new ways of examining and interpreting them. Among the questions about sauropods that have provoked ongoing controversy are even some that—one might think—should have been quickly settled on the basis of the animals’ gross skeletal anatomy: How did they move about, and what postures could they assume? Shorn of their cartilage and ligaments, however, bones can be arranged in unnatural positions, and uncertainties about the range of motion of neighboring bones (as well as over the extent of the animals’ muscular strength) raise doubts about how living sauropods held and moved their bodies and extremities. A century ago paleontologists

and their crews began to install the heavy fossils on mounts for display. In some ways they guessed correctly; in others, investigators now know, they fell wide of the mark. Computers have become part of the discipline’s modern analytic arsenal, and they have already been turned loose on two related

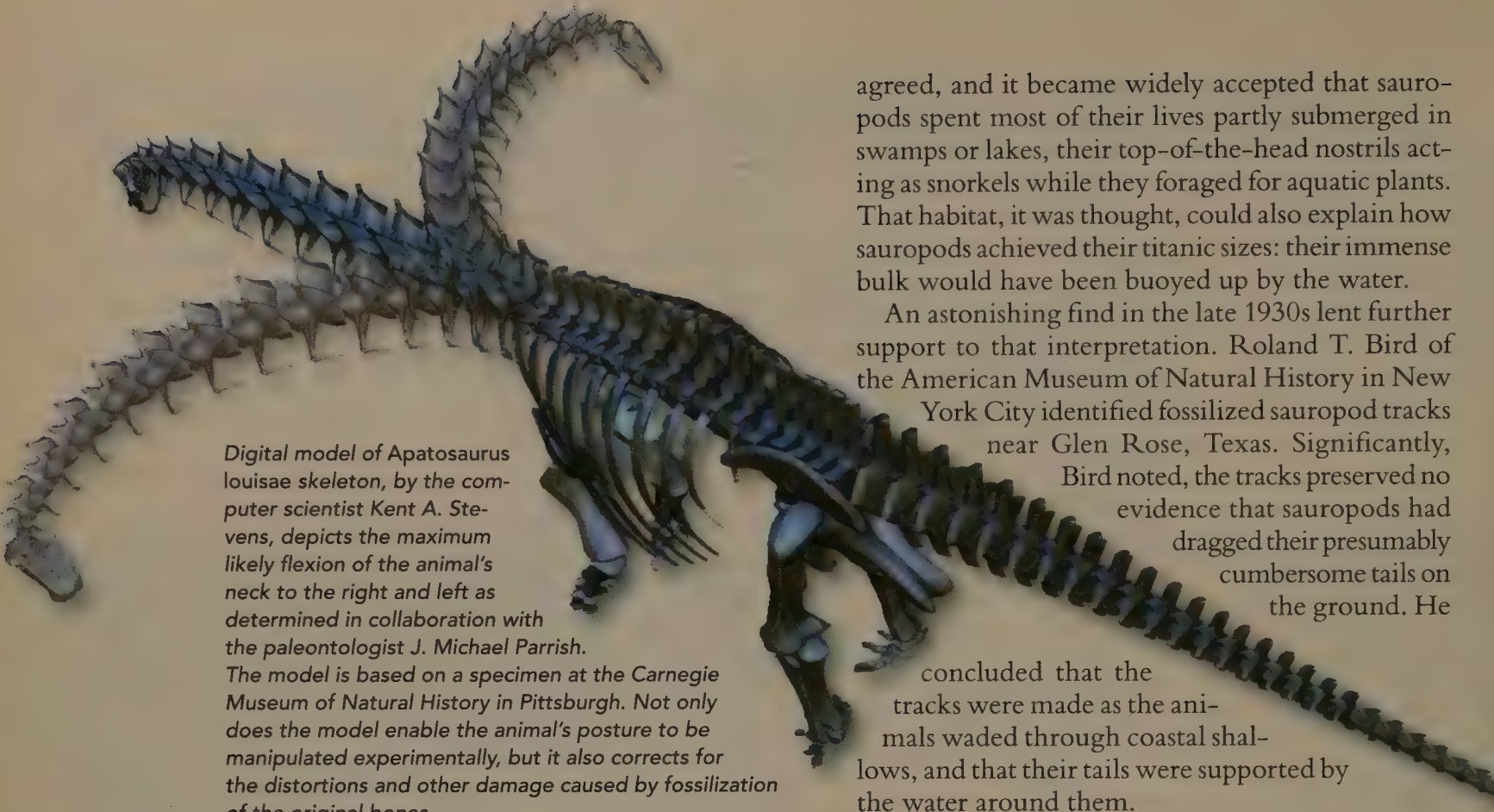
questions: What was the likely orientation of a sauropod neck, and what was its range of motion? Without lifting a single fossil, paleontologists may now have some answers.

In 1877 several vertebrae and the sacrum (the fused vertebrae that connect with the pelvis) of a large



Reconstruction of *Amphicoelias altus* as a water-dwelling creature (upper left), by the artist Charles R. Knight, was made under the direction of the paleontologist Edward Drinker Cope. Published in 1897, it may be the first image to depict a sauropod “in the flesh.” Above: 1910 reconstruction of *Diplodocus*, by Mary Mason Mitchell, followed the views of the paleontologist Oliver P. Hay, who argued that sauropods, like other reptiles, had sprawling limbs. Both reconstructions have now been superseded.

sauropod were discovered near the town of Morrison, in north central Colorado. Then, for the first time in 150 million years, the great reptile trekked across the plains of North America—though not supported on calloused feet and driven by a hunger for vegetation, but carried on steel rails and powered by steam. Awaiting the fossils was the paleontologist Othniel Charles Marsh of Yale College. After examining the bones, Marsh concluded they belonged to a dinosaur, between fifty and sixty feet long, which was then unknown to science. Marsh named the



Digital model of *Apatosaurus louisae* skeleton, by the computer scientist Kent A. Stevens, depicts the maximum likely flexion of the animal's neck to the right and left as determined in collaboration with the paleontologist J. Michael Parrish. The model is based on a specimen at the Carnegie Museum of Natural History in Pittsburgh. Not only does the model enable the animal's posture to be manipulated experimentally, but it also corrects for the distortions and other damage caused by fossilization of the original bones.

species *Apatosaurus ajax*. (Some years later investigators realized not only that Marsh had underestimated the length of the tail, but also that the fossils did not come from a mature individual; adults of the species reached lengths of more than seventy feet.)

Apatosaurus was just one of many dinosaurs to make a name for itself during the late nineteenth century, when Marsh and other paleontologists from the East, notably Edward Drinker Cope of Philadelphia, had crews of men scouring the Badlands of the West in search of ancient beasts. Another of the species Marsh named, in 1879, was *Brontosaurus excelsus*. In 1903, four years after Marsh's death, Elmer S. Riggs of the Field Museum in Chicago determined it belonged to the same genus as *Apatosaurus*. Under the rules of scientific nomenclature, the name *Brontosaurus* was officially retired, though it continued in popular use.

The first description of a complete sauropod skull did not appear until 1884. The skull bore a surprising feature: the external nares—the openings in the skull for the nostrils—were situated not at the tip of the snout, but near the top of the skull, above and between the eye sockets. That position contrasted with the nares of all other dinosaur skulls known at the time. It is characteristic, however, of certain animals that spend most or all of their time in the water, such as whales. Nostrils high on the head are well situated to break the surface and take in air.

Marsh and Cope therefore suggested that sauropods were semiaquatic creatures. Most paleontologists

agreed, and it became widely accepted that sauropods spent most of their lives partly submerged in swamps or lakes, their top-of-the-head nostrils acting as snorkels while they foraged for aquatic plants. That habitat, it was thought, could also explain how sauropods achieved their titanic sizes: their immense bulk would have been buoyed up by the water.

An astonishing find in the late 1930s lent further support to that interpretation. Roland T. Bird of the American Museum of Natural History in New

York City identified fossilized sauropod tracks near Glen Rose, Texas. Significantly,

Bird noted, the tracks preserved no evidence that sauropods had dragged their presumably cumbersome tails on the ground. He

concluded that the tracks were made as the animals waded through coastal shallows, and that their tails were supported by the water around them.

In the second half of the twentieth century, however, paleontologists considered lines of evidence not addressed by Marsh and his colleagues. One approach was to widen the search for anatomical parallels between sauropods and living animals. Distantly related species, flourishing on Earth perhaps millions of years apart, can sometimes look remarkably similar, a phenomenon known as convergent evolution. The similarities result not from common inheritance, but from evolutionary adaptation to similar environmental challenges, diets, or climates.

In the study of sauropods, it proved instructive to compare them to today's elephants, which are also plus-size animals. Beneath the mass of skin and muscle, the long bones of the elephant's limbs are massive, the bones of the wrist and ankle are compact and tightly fitted together, and the bones of the feet and toes are short and compact. In essence, the legs of an elephant are built like the columns of a great temple. Nearly identical features occur in the legs of sauropods. What does the paleontologist make of that? Sauropod legs were similarly adapted to support the animal's weight on dry land.

In some early illustrations, sauropods were depicted not only wading in swamps but, at times, entirely submerged and holding their necks high to breathe at the water's surface [see upper illustration on preceding page]. Those interpretations were particularly unrealistic. An average-size sauropod, such as *Apatosaurus*, would have found it impos-

sible to breathe in that posture. Its chest, some fifteen feet underwater, would have been under too much pressure.

The rocks from which sauropod fossils are recovered also do not support an amphibious scenario. If sauropods were semiaquatic, their fossils should be embedded in the coals of ancient swamps or the limestones formed by lagoons. But that is not always the case. Sauropod bones and tracks are also found in the sandstones typically deposited by and near streams in relatively dry, upland environments. As evidence mounted, the idea that sauropods lived in swamps and other shallow waters was discarded.

As sauropod skeletons were unearthed and transported east in the late 1800s, museums quickly faced the challenge of how to display their trophies, how to assemble the great bones on frameworks of iron and steel. The Yale Peabody Museum unveiled part of its *Brontosaurus* (*Apatosaurus excelsus*) in 1901. But the first nearly complete skeleton of a sauropod to be put on display was the *A. excelsus* belonging to the American Museum of Natural History [see photograph on page 34]. Opened to the public in 1905, it was labeled *Brontosaurus*, technically a name that had been retired.

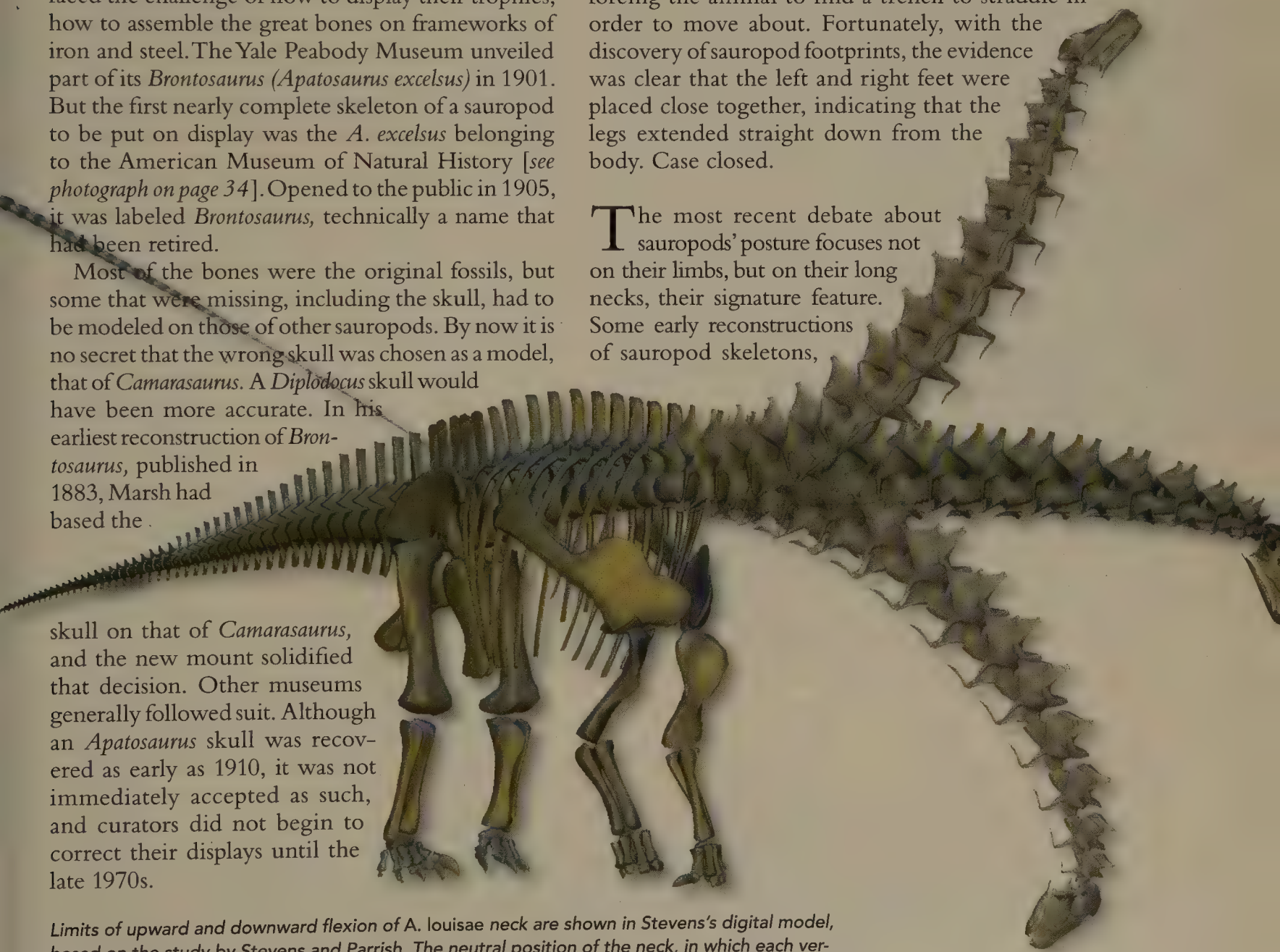
Most of the bones were the original fossils, but some that were missing, including the skull, had to be modeled on those of other sauropods. By now it is no secret that the wrong skull was chosen as a model, that of *Camarasaurus*. A *Diplodocus* skull would have been more accurate. In his earliest reconstruction of *Brontosaurus*, published in 1883, Marsh had based the

skull on that of *Camarasaurus*, and the new mount solidified that decision. Other museums generally followed suit. Although an *Apatosaurus* skull was recovered as early as 1910, it was not immediately accepted as such, and curators did not begin to correct their displays until the late 1970s.

Limits of upward and downward flexion of *A. louisae* neck are shown in Stevens's digital model, based on the study by Stevens and Parrish. The neutral position of the neck, in which each vertebra is aligned in contact with the one in front and the one behind, was essentially horizontal. Even at the upward limit, the neck posture was not as vertical as that in giraffes, to which sauropods have often been compared. Nevertheless, the head could reach five feet below ground level, suggesting the animal could stand on shore and browse on aquatic plants.

Disagreement over just how the bones fitted together was inevitable. Before the discovery of sauropod tracks, a fundamental issue (literally!) was the position of the legs. The American paleontologist Oliver P. Hay and the German anatomist Gustav Tornier maintained that, since dinosaurs were reptiles, the legs of sauropods must have functioned like those of a lizard or a crocodile, sprawling out from the side of the body [see lower illustration on page 35]. Others strongly disagreed. In 1910 William J. Holland of the Carnegie Museum of Natural History in Pittsburgh countered that for a sauropod to have adopted a reptilian sprawl, the joints of the legs would have had to have been severely dislocated. Furthermore, a sprawling posture would have caused a sauropod's deep rib cage to project below its feet, forcing the animal to find a trench to straddle in order to move about. Fortunately, with the discovery of sauropod footprints, the evidence was clear that the left and right feet were placed close together, indicating that the legs extended straight down from the body. Case closed.

The most recent debate about sauropods' posture focuses not on their limbs, but on their long necks, their signature feature. Some early reconstructions of sauropod skeletons,



including the ones by Marsh and by the American paleontologist and fossil-hunter John Bell Hatcher, projected the neck forward from the body, in a near-horizontal, or even downward-sloping, position. But given the length of sauropod necks, it was hard not to look to giraffes. Although giraffes frequently feed on low-growing vegetation, the natural posture of the giraffe neck is the extended, near-vertical position. By analogy, images proliferated of sauropods holding their

necks upward to browse from the tallest trees.

But do the fossils themselves corroborate an elevated neck? To investigate that is no easy matter, for one major reason: the fossils are really big. The weight of just one fossilized bone can cause great pain to the lower back of any paleontologist foolish enough to attempt a lift. With no ready means to manipulate the bones of a skeleton, or even to move lighter full-size casts, the paleontologist's ability to test sauropod biomechanics—how those giants moved—has been extremely limited.

All of that changed in 1999, when Kent A. Stevens, a computer scientist at the University of Oregon in Eugene, and J. Michael Parrish, a biologist and paleontologist at Northern Illinois University in DeKalb, published a landmark study that challenged the picture of high-browsing sauropods. With a computer program called DinoMorph, Stevens created digital models of sauropod skeletons. In so doing he and Parrish not only freed themselves from handling full-size fossils or casts, but they could also digitally remove distortions in the original vertebrae left by fossilization.

The DinoMorph models of *Apatosaurus* and *Diplodocus* skeletons led to surprising results: once the neck vertebrae were neutrally aligned, each in perfect contact with the one in front and the one behind, the neck extended forward from the shoulders at a slight downward angle, bringing the head near the ground. That posture harkened back to the original reconstructions of Marsh and Hatcher.

Moreover, the necks of the two sauropod species proved relatively inflexible, compared with the way many common reconstructions portrayed them [see *illustrations on the two preceding pages*]. From a normal standing position, *Apatosaurus*, with a shoulder height of ten feet and a neck length of seventeen feet, could raise its head no more than twenty feet above the ground. *Diplodocus*, whose neck was three feet longer but even less flexible, could reach only thirteen feet high, from a shoulder height of nine feet. Both *Apatosaurus* and *Diplodocus* could sweep their heads thirteen feet to the left or right: again, less flexibility than had often been portrayed. Yet both could bend the neck down, lowering the head as much as five feet below ground level.

The new evidence suggests that *Apatosaurus* and *Diplodocus* were probably best suited for feeding on low-growing plants. Perhaps the two sauropods were even given to standing along the edges of rivers or lakes, lowering their heads to feed on plants in the water. It is a somewhat ironic commentary on the scientific method to realize that information-age pixels have led investigators back to the idea that Marsh and his colleagues first proposed in ink more than a century ago. *Apatosaurus* and *Diplodocus* are back to their diet of aquatic plants. Now, though, they're enjoying the view from shore.

What does the future hold for the understanding of sauropods? One emerging issue is the position of their nostrils. In spite of the nares at the top of the head, Lawrence M. Witmer, an anatomist at Ohio University in Athens, argues that the actual fleshy openings were much nearer the tip of the snout. He bases his view on comparisons of sauropod bones with those of crocodiles, lizards, and birds. Once again, a long-held truth is being questioned.

In 1863, four years after Darwin revolutionized the biological sciences with his *Origin of Species*, Thomas H. Huxley published a collection of three short essays titled *Evidence as to Man's Place in Nature*. Throughout the work, Huxley shared his thoughts on human evolution and our close kinship with the apes, but he recognized that, with future discoveries, his conclusions might not stand. So it is with the study of sauropods. For now, we specialists think we have them right. But as Huxley concluded in his third essay, "Time will show." □

For more information about sauropod dinosaurs, go to www.naturalhistorymag.com and click "Online extras," then "Web links," and finally "April 2007" to find links related to this article.



Sauropod tracks, now fossilized in Upper Jurassic rocks at Termas del Flaco, Chile, were made between 145 million and 150 million years ago.

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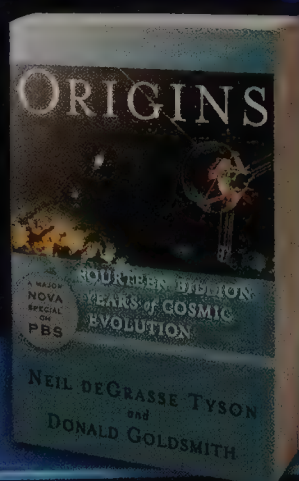
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Vulcan's Masonry

The builders of ancient Rome clad soft, porous volcanic tuff with harder travertine and marble, creating enduring, majestic structures out of local materials.

By Marie D. Jackson

Walk with me through the Roman forum, but imagine it through the eyes of an ancient Roman from the provinces, visiting the capital for the first time in many years. It is exactly 2,000 years ago. As we walk along the familiar Sacred Way through the new arch of Augustus, surrounded by monuments that exemplify the timeless excellence of our public architecture, you'll recognize the splendid new renovations to the ancient Temple of Castor and Pollux. Now the Basilica Julia is on our left, with its luminescent rows of marble columns still under construction. Let's continue forward, past the

elaborate enlargements underway at the Temple of Concord.

I sense your pride in this splendid public space, and I share it. We live in a great *urbs*, in a time of high cultural accomplishment. There's more: a short walk will take us to the new forum that our emperor, Augustus (you remember him as Octavian, the nephew and later the adopted son of Julius Caesar), has constructed to celebrate the religious and historical foundations of his ascent to supreme power over the growing Roman Empire.

At the center of the Forum of Augustus is the magnificent Temple of Mars Ultor (Mars the Avenger).



Temple of Mars Ultor, shown dressed in marble in a hypothetical reconstruction (above) and as it is today (opposite page), was the focal point of the Forum of Augustus. Some marble is still present in the remains of a few columns and as cladding on a few steps, but the Romans constructed the temple mainly from local volcanic rock that they then faced with marble. One kind of volcanic rock, so-called Tufo Lionato (brown stone in the cutaway section in the center foreground, above), is still visible under the columns and in the left wall of the forum. Lapis Gabinus (gray stone in the reconstruction) makes up the bulk of what was once a hundred-foot-high boundary wall, built to protect the temple from fire. The white line of stone in the remains of the boundary wall is travertine, a sedimentary stone also quarried locally, which looks much like marble.

This temple is dedicated to the god of war for avenging Rome after the assassination of Julius Caesar. Notice how the steep staircase rises to the portico, the temple's open entryway, with its eight lofty, fluted marble columns topped with intricate Corinthian capitals. What is most extraordinary, Augustus has had a fire-resistant boundary wall built against the back of the temple.

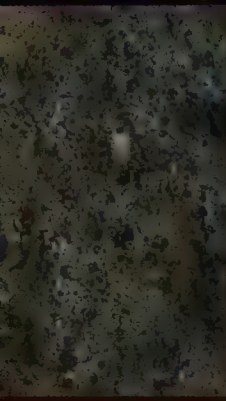
Today, two millennia after its construction, the modern visitor's first impression of the Forum of Augustus is that there is very little left. The Augustan building program transformed Rome into an imperial capital glowing with imported marble; by now, however, over the centuries, most of the marble from the Temple of Mars Ultor and its surrounding structures has been carried away. But the structures of the forum also reflect the building materials and techniques that the Roman architect

and engineer Marcus Vitruvius Pollio considered important. And as if to prove his point, dark gray and reddish brown volcanic tuffs—known as Lapis Gabinus (stone from Gabii) and Tufo Lionato (lion-colored tuff)—of the forum walls and temple foundation remain largely intact.

Construction on the Forum of Augustus began in the late first century B.C., soon after Vitruvius completed a treatise titled *De architectura* ("On Architecture") that he dedicated to the emperor. The treatise is the only comprehensive account of Roman architecture to survive from classical antiquity. In it, Vitruvius recorded the empirical observations of largely anonymous Roman builders and stonemasons, who were well acquainted with their volcanic landscape and the building stones it provided. He also described their technique: use the volcanic tuffs as lightweight, readily quarried



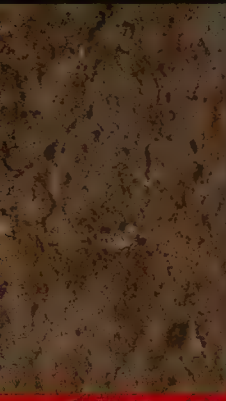
Travertine



Lapis Gabinus



Tufo di Tuscolo



Tufo Lionato



Tufo Giallo

building stone, then face the tuff construction with a veneer of more durable stucco, travertine, or marble. The expertise of the Roman stonemasons was fundamental to the Augustan building program, and many of the principles of stonemasonry, as set down in *De architectura*, are reflected in what remains throughout the forum.

To make a close study of Roman building and its principles, my colleagues and I formed a multidisciplinary research team that integrates geological fieldwork, petrographic, mineralogical, and engineering studies of the Roman rocks, and a new translation of Vitruvius' report on building materials. Our team includes Fabrizio Marra, a geologist at the National Institute of Geophysics and Vulcanology in Rome; the late Richard L. Hay, who was a mineralogist most recently at the University of Arizona in Tucson; Carl G. Cawood, a civil engineer at Northern Arizona University in Flagstaff; and Cynthia Kosso, a historian who is also at Northern Arizona University.

Our work has aimed to grasp the depth of Vitruvius' understanding of natural objects and processes. His empirical observations of the diverse characteristics of locally quarried building stones enabled him to select the best combinations of rocks for cut-stone masonry. Indeed, our study shows that the durability of Roman monuments can be traced, in part, to the innovations of Roman builders: the existing monuments are a testament to their creativity, their willingness to experiment, and their practical genius for making the most of the relatively soft and weak volcanic tuffs at hand. The Roman builders created the public expression of a new world order under Rome's first emperor.

Many schoolchildren know that Rome is built on seven hills. Few, however, learn that the hills are overlain by volcanic deposits. In fact, the topography of the central Italian peninsula carries the strong imprint of volcanoes—Mount Vesuvius, for instance, last erupted in 1944.

Beginning about 560,000 years ago, explosive eruptions from the Sabatini Mountains and the Alban Hills [see map on this page] deposited large volumes of volcanic material over the area that would become Rome. That material, known as tephra, included particles of glass, crystal, and rock in assorted sizes, which were transported through the air or across the ground. The tephra cooled and consolidated,



eventually developing natural mineral cements to form a kind of porous, volcanic stone called tuff.

Early stone construction in Rome, during the sixth and fifth centuries B.C., made use of the soft volcanic tuff from within the city; it was widely available, literally underfoot, and easy to extract, requiring little more than saws and hand tools. Those early Romans quarried stone along hillsides and in underground chambers beneath the Palatine and Capitoline hills. Unfortunately, the stone was of low quality and crumbled readily under stress. At the end of the fifth century B.C., however, the Romans conquered the nearby Etruscan cities to the north, gaining access to the more durable varieties of tuff along the Tiber River. In the fourth century B.C., they built the Via Appia (Appian Way) to the south, along which oxcarts transported good-quality tuff building stones back to Rome.

The Romans also began to quarry the area around Tibur (modern Tivoli) for travertine, a hard, slightly yellowish or grayish white sedimentary rock that formed in a shallow lake when calcium carbonate precipitated from mineral-rich waters warmed by nearby volcanic activity. To the untrained eye, ivory-colored travertine can pass as marble; on closer inspection, however, distinctive hummocky mounds are visible, made up of the fossilized remains of calcite-precipitating bacteria.

By the time Vitruvius wrote *De architectura*, Ro-

mans were calling on seven kinds of tuff, along with travertine, to develop an innovative architecture based on cut-stone masonry integrated with small, functional elements of concrete. Vitruvius describes the material characteristics of Roman tuff, travertine, and lava building stones in detail:

Now order demands that I explain about quarries, from which both squared blocks and the supplies of rough, unhewn stone for building are obtained and readied. These, in turn, will be found to have unequal and dissimilar qualities. Some are soft and yielding around the city itself, in the manner of the *rubrae* stones, the *pallenses* stones. . . . Some are of moderate strength, like the *tibur* stones, . . . and others of this type. Some are hard, like lavas.

The *rubrae*, or red, stones were reddish brown Tufo Lionato excavated near Salone, along the Aniene River; the *pallenses* were pale yellow Tufo Giallo della Via Tiberina (“yellow tuff from the Tiber Road”), extracted near Grotta Oscura; and the *tibur* stones were travertine [see map on opposite page].

In his *Geographica*, Strabo, a Greek geographer and a contemporary of Vitruvius, highlights the trio of building stones used in the Forum of Augustus for their proximity to the city of Rome:

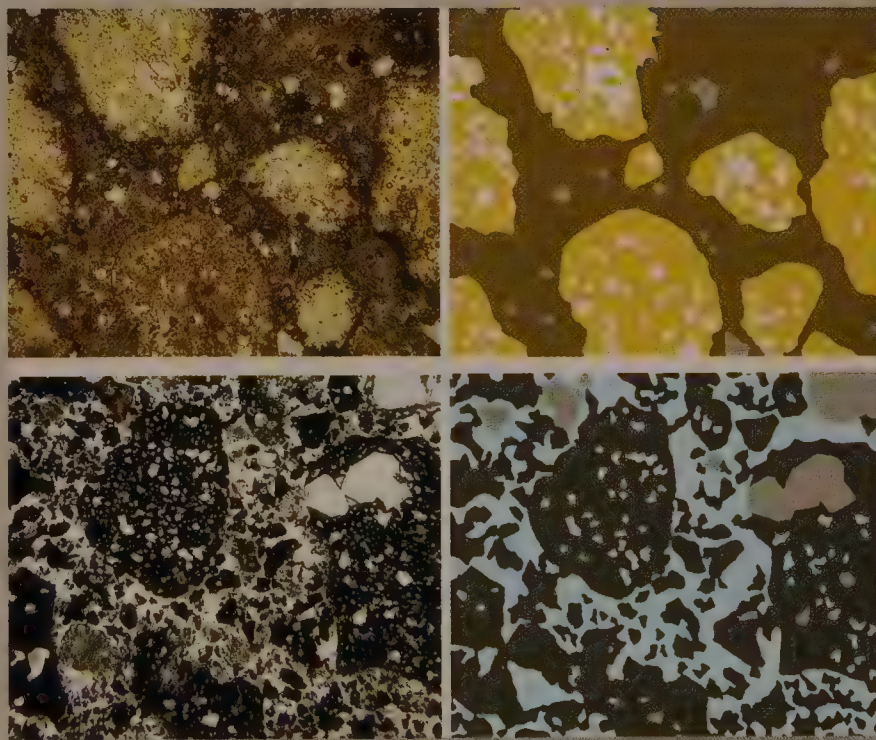
The [Aniene] river flows out through a very fruitful plain past the quarries of Tiburtine [travertine] stone, and of the stone of Gabii [Lapis Gabinus], and of what is called the “red stone” [Tufo Lionato]; so that the delivery from the quarries and the transportation by water are perfectly easy.

Much farther afield, about 200 miles northwest of Rome, were the quarries near modern Carrara, Italy, which supplied the marble employed in the Temple of Mars Ultor. Marble is a metamorphic rock formed by the recrystallization of sedimentary carbonate rocks, such as limestone. The strength of Carrara marble is similar to that of travertine from Tivoli. But its beauty when polished is unparalleled, because light readily penetrates its surface, giving the stone a luminous, vibrant glow.

The late Richard Hay, a mineralogist with a lifetime of experience studying volcanic rocks, and I made detailed, microscopic observations of the tuffs sampled from ancient Roman quarries. Our aim was to identify their mineralogical components and associate them with the physical properties of the composite building stones. Generally, the glassy Roman tuffs were quarried from ignimbrites—rock formed from voluminous flows of hot gases and fine-grained glass fragments that solidified after an explosive eruption. The building stones made of Tufo Giallo and Tufo Lionato came from massive ignimbrites with little internal structure or layering.

In contrast, Lapis Gabinus includes abundant lava rock fragments. When hot magmas encountered water underground or at the surface, powerful explosions fractured older rocks, mainly lava and sometimes limestone, that lay beneath the vent of the volcano. The coarse rock fragments of lava became intermixed with the magma, and so the tuffs include abundant embedded fragments of dark-gray lava and occasional bits of light, yellowish gray limestone. Italians call the texture peperino, because it reminds them of ground black pepper. One such peperino tuff was Lapis Gabinus, still visible in the tall boundary wall of the Forum of Augustus.

Vitruvius clearly understood the poor durability of the Roman tuffs: “So long as these soft stones are sheltered under stucco they will hold up and do their work,” he wrote. “But if they are laid bare or exposed in the open air, ice and frost accumulate within them, and they crumble apart and dissolve.” Indeed, all the tuffs readily take up water, and when they do, they lose between 15 and 40 percent of their dry strength. They are particu-



Micrographs highlight the differences between hard and soft volcanic tuffs. Tufo Giallo (top left), a relatively soft tuff, includes numerous fine fragments of glass (dark brown in the diagram at top right) and pumice (yellowish brown), which readily absorbs water; the soft tuff also has many cavities (white), formed by gas that was trapped as the stone solidified, but only a few crystals (gray). Both the pumice and the cavities contribute to the tuff's vulnerability. Harder tuffs such as Lapis Gabinus (above left) include a great deal of robust lava rock (dark gray in diagram, above right) and hard crystal (light gray), all held together in a matrix of natural cement (light blue). The images are magnified 11X.

larly susceptible to decay when they are directly exposed to daily fluctuations in relative humidity, to winter rains, and to the freezing temperatures to which Rome is sporadically subjected.

One way to address the problem of decaying soft tuffs, such as Tufo Lionato and Tufo Giallo, was to allow them to dry in the open air and then select only the best-quality blocks for cut-stone masonry. Vitruvius describes the process:

When it is time to build, the stones should be extracted two years before, not in winter but in summer; then toss them down and leave them in an open place. Whichever of these stones, in two years, is affected or damaged by weather should be thrown in with the foundations. The other ones that are not damaged by means of the trials of nature will be able to endure building above ground.

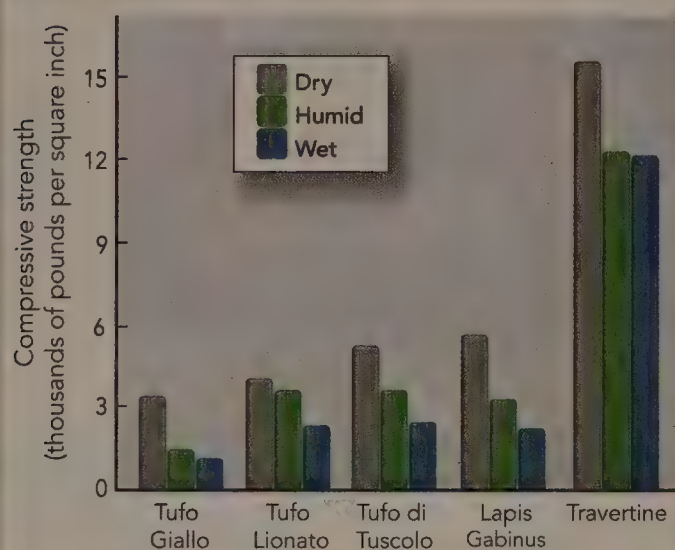
Roman builders had another way of dealing with tuff decay: They seldom left tuff masonry exposed. Instead, they preserved the porous stone with stucco or with travertine or marble cladding, whose water

di Tuscolo (tuff from Tuscolo), both reinforced and clad with travertine [see photograph on opposite page]. The structure stood three stories high and incorporated forty-one arches with travertine facings, which are preserved on part of its external facade. Even today the structure preserves an impressive array of Tufo di Tuscolo arches reinforced with travertine keystones and imposts (the uppermost parts of the columns supporting an arch's span).

To assess Vitruvius' descriptions of the relative strengths and durability of Roman building stones, Carl Cawood and I designed rock-testing experiments under oven-dry, humid, and water-soaked conditions. The tests were intended to approximate Roman climatic conditions and their effects on tuffs and travertine [see illustration on this page]. Glassy tuffs, such as Tufo Giallo and Tufo Lionato, have low compressive strengths—they fracture and fall apart under moderate pressures. Both of those tuffs incorporate abundant volcanic glass fragments, including pumice, a frothy glass [see micrographs on preceding page]. And both are highly porous, readily absorbing water when, for instance, the Tiber River floods or the relative humidity is high. Water absorption greatly reduces their weight-bearing strength.

Compared with the glassy tuffs, we found that tuffs that incorporate an abundance of lava and crystal fragments, such as Lapis Gabinus and Tufo di Tuscolo, have higher compressive strengths—they can bear higher pressures without fracturing. The lava fragments provide an interlocking framework of hard grains to which natural mineral cements within the tuff strongly adhere. Moreover, these tuffs are denser, take in less water, and have greater elasticity than brittle Tufo Giallo and Tufo Lionato.

"True travertine from Tivoli and all stones of the same type withstand heavy loads and harsh weather," noted Vitruvius, "but from fire they cannot be safeguarded. And similarly, when they touch fire they crack apart and fall to pieces." Our rock-testing experiments confirm those observations as well. Travertine has far greater compressive strength than the tuffs. Its water absorption is low, less than 1 percent of the total weight of the stone, and so in rain or high relative humidity, travertine retains about 80 percent of its compressive strength. Travertine both reinforced and protected soft-tuff masonry in Roman architecture. Yet, again in accord with Vitruvius' observations, stone formed of calcite crystals—travertine, limestone, and marble—fractures when subjected to the intense heat of urban fires, which often exceed 1,500 degrees Fahrenheit. At high temperatures, calcite lengthens along one crystallographic axis and shrinks along its perpendicular



Compressive strength, or the greatest weight-bearing pressure a stone can withstand before fracturing, is plotted for several important building stones used in ancient Rome. Roman builders and architects were well aware that tuffs are weak when water-soaked, as Vitruvius states. Hence they clad the tuff masonry with travertine facings to reinforce it and protect it from direct exposure to moisture.

absorption is far less than that of the tuffs. That strategy made for strong, lightweight buildings that were nonetheless attractive and resembled the marble structures of ancient Greece. A stroll through modern Rome reveals many ancient columns constructed of tuffs, some of which still retain protective cladding or semipermeable coatings of stucco. For example, the Theater of Marcellus, dedicated by Augustus in 13 B.C. to commemorate the death of his young nephew, was constructed mainly of cut-stone Tufo



Theater of Marcellus, pictured as it exists today, was dedicated by Augustus in 13 B.C. It was constructed mainly of cut-stone Tufo di Tuscolo (tuff from Tuscolo), also used in the construction of the Colosseum eighty years later. The structure was reinforced and clad with travertine. Visitors today marvel at the structure's array of Tufo di Tuscolo arches (brownish stone), reinforced with travertine (white stone) in the keystones and imposts, or tops of the columns that support the two sides of an arch's span. The finished wall in pink brick is a modern restoration.

axes; such uneven thermal expansion and contraction create internal stresses that shatter the stone.

Returning to the Forum of Augustus, we can now begin to appreciate the architectural skill and the knowledge of natural materials that underlay its ornamental facings of Carrara marble. The complex tuff masonry of the forum, along with stabilizing travertine cut-stone masonry, were entirely hidden from view. Suetonius, a Roman historian writing in the early second century A.D., comments: "Since the city was not adorned as the dignity of the empire demanded . . . , [Augustus] so beautified it that he could justly boast that he had found it built of brick and left it in marble." In the *Res Gestae*, Augustus' autobiographical catalog of personal achievements, the emperor enumerates the many new monuments he constructed and the many public buildings, temples, and bridges he repaired. Those works often required that marble facings be installed over tuff block-work or functional concrete masonry. As Augustus transformed the stucco-covered tuff buildings of Rome into elegant, marble-clad structures, he created a magnificent imperial capital whose architectural glories still stand today.

In sum, however, none of that would have been possible without the genius of Roman builders in the first century B.C. Their lasting achievements depend, in turn, on their astute observations, as natu-

ral scientists, of the diverse material characteristics of the rocks that formed the surrounding volcanic landscape. They selected certain tuffs for specific structural elements, on the basis of their durability and weight-bearing strength. They used lava rock—rich Lapis Gabinus and Tufo di Tuscolo in foundations and in weight-bearing walls, and glass-rich Tufo Giallo and Tufo Lionato in second-story walls and in concrete vaults. The technological choices recorded in the classical Roman monuments and in *De architectura* reflect Roman builders' empirical understanding of the role of particle composition and the relative proportions of glass, crystal, and rock fragments in determining the durability of the tuff building stones.

For centuries, ancient Roman tuff building stone remained buried or protected within renovated monuments. Archaeological excavations of the past two centuries have now exposed the tuffs to accelerated decay. To prevent further deterioration and eventual corrosion, the tuff building stones should be placed under protective cover, as Vitruvius recommended more than 2,000 years ago. □

For more information about ancient Rome, go to www.naturalhistorymag.com and click "Online extras," then "Web links," and finally "April 2007" to find links related to this article.



Chicago by night

*The Grid: A Journey Through
the Heart of our Electrified World*
by Phillip F. Schewe
Joseph Henry Press; \$27.95

Benjamin Franklin, for all his scientific acumen, never dreamed that the electricity he tinkered with would someday join food, water, shelter, and clothing on the list of bare necessities. Yet here we are in the twenty-first century, profoundly dependent on the slender wires that connect us to the grid. Without electricity, food would spoil, pumps would not deliver water, our homes, bereft of heating or cooling, would soon become unlivable and our clothes, unwashed, would soon become unwearable. Consider the inconveniences, major and minor, that accompany a sudden blackout, such as the one that paralyzed the northeastern United States in the summer of 2003—people trapped in elevators, gasoline pumps shut down, streets turned dark and dangerous.

To be off the grid, in short, is to be out of the mainstream of modern culture—which is why, except for a few back-to-the-landers and Old Order Amish, everyone in the world is, or wants to be, plugged in. Phillip F. Schewe, in his eclectic survey of the past century and a quarter of electrification, casts a perceptive eye on how that momentous transformation came about, and where it may be heading.

Thomas Edison, not surprisingly, was the father of the grid. At 3 P.M. on September 4, 1882, he threw a lever in his first power plant at 255–57 Pearl Street in Manhattan, sending current along a network of underground wires to 400 electric lamps in buildings nearby. By November, the number of lamps drawing sustenance from Pearl Street had tripled, and within a year *The New York Times* had 300 bulbs burning in its own building. Edison power plants and electrical lines were soon going up in Budapest, Milan, Moscow, Santiago, and a host of other cities around the world.

But if Edison deserves the credit for engineering the first centralized electric power system, other, lesser-known heroes are responsible for its kudzulike growth. Power plants like the Pearl Street station were not suited to today's nationwide grid because they produced direct current (DC), a current that flowed steadily in one direction. The problem was that DC current could not, at the time, be sent over long distances without substantial losses of energy.

The solution was AC, or alternating current, whose flow reversed itself many times a second. The rapid reversals made it possible to step AC current up to a high voltage, which loses less energy than low-voltage current during transmission. At ultrahigh voltages, AC current could transport power efficiently over wires for hundreds of miles.

The first entrepreneur to make the connection between AC current and the business potential of long-distance energy distribution was George Westinghouse. Not long after Pearl Street produced its first power, Westinghouse began setting up a network of generating stations and transmission lines based on AC. The idea was to site power plants where energy was abundant, near coal mines and waterfalls, and send it to faraway urban centers where potential users were concentrated. Equally important, Westinghouse hired an immigrant engineer named Nikola Tesla. Brilliant and unconventional, Tesla designed efficient AC generators to make electricity cheaply, and compact AC motors that were more convenient and reliable than the steam and water turbines then common in workshops and factories.

Although Schewe has a Ph.D. in physics and writes a weekly newsletter for the American Institute of Physics, his book focuses less on engineering and more on the political, economic, and cultural challenges that the growth of the grid entailed. Maybe that's not so surprising: Schewe is also a playwright whose works have been staged in New York and Washington, D.C. *The Grid* may never make it to Broadway, but, to use Schewe's phrase, it is a "drama of volts," illuminating an aspect of our world that most of us too often take for granted.

*Steller's Island: Adventures
of a Pioneer Naturalist in Alaska*
by Dean Littlepage
The Mountaineers Books; \$17.95

At the Zoological Institute of the Russian Academy of Sciences in St. Petersburg is a slab of white bone with an oddly ridged surface. The ridges seem to serve no obvious physiological purpose—unless perhaps one is an expert in the oral anatomy of extinct species. The bone comes from the mouth of a giant marine mammal, Steller's sea cow, which once used a pair of these plates in place of teeth to masticate long strands of kelp it pulled

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from the frigid waters of the North Pacific. The animal bears the eponym of one of the first and last Europeans to see a live sea cow in its native habitat: Georg Wilhelm Steller, the young naturalist on Vitus Bering's pioneering voyage to the Aleutians and along the coast of Alaska that embarked from Siberia in 1741.

So difficult was Arctic travel in those days that it was fortunate that anyone at all survived to describe the sea cow. Almost half of the expedition's company, including Bering himself, died of scurvy before the voyage was over. Shipwrecked on a remote island, the company spent the winter of 1741–42 huddled in improvised shelters. Not until the following August did Steller and forty-five survivors finally limp back to a Siberian port in a boat made from the wreckage of their original sailing craft. The palate bone, as a consequence, is one of the few artifacts



Skeleton of Steller's sea cow, a giant marine mammal

Steller collected that managed to make it back to civilization.

What did come out of the trip were Steller's observations, collected in his monumental monograph, *The Beasts of the Sea*, first published in 1751. And among the marine mammals Steller discusses in his book, most of them only vaguely known to European biologists of the time, sea cows were by far the largest. He and his shipmates managed to kill a full-grown female and dissect it on the beach, the only extant scientific report of one in the flesh.

Looking at sketches of the creature, the modern observer sees something like a stretch-limo version of a sea lion, its blimpish body connecting a two-lobed tail and a flattened snout. Steller's specimen measured twenty-five feet from nose to tail. Its tongue was a foot long, its blubber was six inches thick, and its stubby front flippers were equipped with claw-like appendages that helped it dig kelp strands from rocks.

To survive in cold water, it must have consumed enormous quantities of food. Its stomach was the size of a large walk-in closet, and its digestive tract, when unfolded along the shore, stretched 500 feet from mouth to rectum, twenty times the creature's length. (For comparison, the human digestive tract is only about five times an average person's height.)

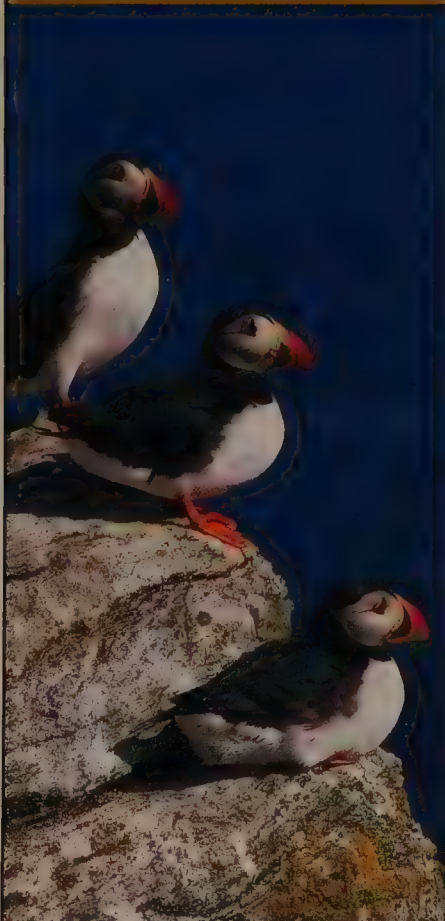
Steller observed a population of sea cows that was barely able to survive; their habitat had probably been warmer when they migrated to the Arctic millions of years earlier. Even if they had not been hunted to extinction by 1768, they might have disappeared.

Steller also described a variety of other creatures that survive today—an incredible act of scientific discipline since, as a castaway in a cold and bitter land, he had to struggle merely to stay alive. He was an acute observer of the physical characteristics and behavior of such creatures as sea otters, sea lions, and northern fur seals. He noted, for instance, that the sea otter, which had little body fat, managed to insulate itself by continually growing a new coat and shedding its old one, a few hairs at a time.

Dean Littlepage, an Alaskan writer, re-creates Steller's adventures, drawing heavily on the logbooks and journals of Steller and his companions. There's a bit of Littlepage's own expertise in outdoor journalism on display here too, as the author backpacks around Kayak Island, where Steller first came ashore in North America. It's no longer a blank

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spot on the map, as it was in Steller's time, but Littlepage helps the reader understand the excitement the young explorer must have felt 250 years ago, fresh-eyed and eager to be amazed.

Flower Confidential: The Good, the Bad, and the Beautiful in the Business of Flowers

by Amy Stewart
Algonquin Books of Chapel Hill
\$23.95

Sitting down to write this review, a scant forty-eight hours before Valentine's Day, I realized that, like more than 55 percent of my fellow holiday gift-givers, I have not yet bought any flowers. That curious statistic comes from *Flower Confidential*, which strips bare more about the cut-flower industry than most people buying a heartfelt bouquet would want to know.

In the case of the roses for my beloved—which I swear I will order in just a few minutes—Amy Stewart tells me

that their form and fragrance may have been designed by a corporate breeding laboratory in Holland or California. But, she goes on, they were probably grown in a crowded greenhouse in the Andes. Around the beginning of January, local laborers made the rounds of the hothouse aisles, placing little mesh sleeves (aptly nicknamed *condones*, or “condoms”) over each bud of “my” roses to keep them from opening too soon. A month later, the workers cut each stem, dipped each flower into a barrel of fungicide, and arranged the swelling buds in bunches for shipping.

Large trucks ferried the crop to the airport, where it was placed on a plane. Purchased by an export firm, the flowers were soon bound for New York or Miami. From there they were trucked, as rapidly as possible, to my local florist. And as soon as I make my phone call, he will add a few garnishes and flourishes



At work in a Colombian flower factory

and deliver them, with the appropriate message of devotion, sometime before the sun has set on February 14—less than a week after they began their journey from South America.

Stewart takes her readers on every stage of this odyssey, with a critical eye and the panache of a seasoned journalist. A confessed flower junkie,

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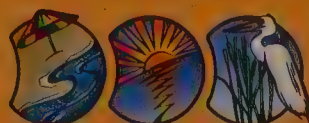
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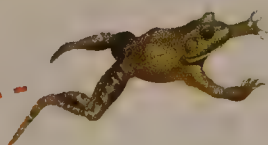
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No Bones About It

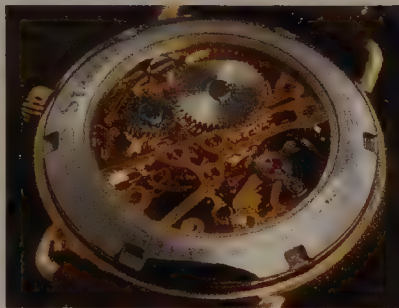
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she can't resist the blooms, even when she's visiting a flower plantation on the industrial scale. "As I stood ... and looked out across several dozen rows of sunny orange gerberas in bloom," she writes from Holland, "I thought that I'd probably never seen so much exuberance in one place. This is not a flower with nuance. It radiates pure, uncomplicated happiness."

Elsewhere, she shops for flowers the way Imelda Marcos must have shopped for shoes:

I fell hopelessly in love with this store when I was in Miami and spent an entire day driving from one Field of Flowers location to the next because I just couldn't get enough of it. ... I was hooked. I filled my drab hotel room with odd and unusual flowers I picked up at the three shops, and left them behind for the housekeeping staff to wonder about.

But Stewart is no Pollyanna. As her title suggests, she does not view the flower business through rose-colored glasses. Most flowers for the trade are no longer grown on family farms and sold by elegant old ladies—if they ever were. They are commodities, and as such are fully enmeshed in the creeping ivy of globalism. Flower workers, particularly in developing nations where mass-market blooms are grown, endure long hours and may suffer the effects of poorly regulated pesticides. By the time the five dollars I might pay for an up-market rose stem in New York City trickles down to the laborer who harvested it, only a few cents remain for his or her time and effort.

Consider, then, the lilies of the field, Stewart is saying—and all they go through on the way to your table. "If it seems like flowers have lost their soul in this process," she concludes, "well, they have."

LAURENCE A. MARSCHALL, author of *The Supernova Story*, is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.

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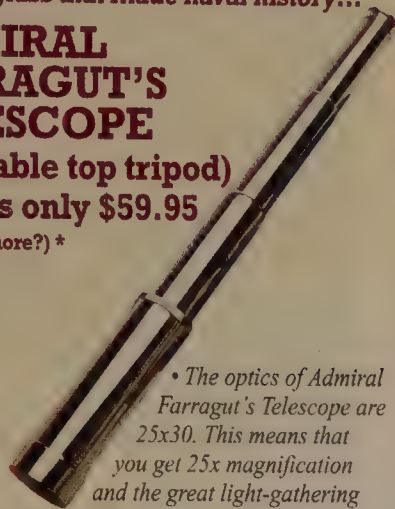
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Pop Charts

By Robert Anderson

Nowadays, when I fly, my two children compete for the window seat. But I remember when I used to be glued to the airplane window on approach to Los Angeles. The grid of streets and the sinuous system of freeways spread out for hundreds of square miles before me was always a vivid reminder of the remarkable expansion of our species. Just before landing, I would also note the traffic grinding along the 405 freeway. Our reproductive success, it seems, exacerbates almost every problem we face, from regional conflicts to global warming and the loss of biodiversity.

On the Internet scores of organizations analyze the numbers, sound warnings, and offer ways to soften the impact of future population growth. NOVA's Web site "World in the Balance" (www.pbs.org/wgbh/nova/worldbalance) is a good introduction to the subject. Beneath the heading, a "pop-clock"—a ubiquitous feature on population sites—counts each moment's increase in our numbers (as I write, it is speeding past 6,569,308,148). In the "Interactives" section, click on "Human Numbers Through Time" for a series of nine maps that show the spread of our species across the globe (to animate the maps, click through to the last one and then select "play all," which appears just above the map on the right). For authoritative current statistics on many of the social factors that affect birthrates throughout the world, go to the Population Reference Bureau (www.prb.org) and click "Datafinder."

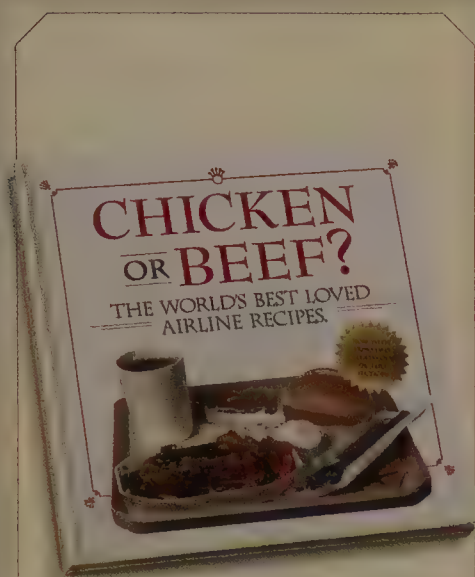
Globally, in this century, the least developed regions will undergo nearly all the growth. For a quick look at where people live, go to the Hive Group (www.hivegroup.com/world.html), which specializes in visualizing business data. Here you can readily compare the populations of various countries.

The Social and Spatial Inequalities

Research Group at the University of Sheffield in England has an addictive Web site called Worldmapper that shows how humanity and resources are distributed (www.sasi.group.shef.ac.uk/worldmapper). The countries are sized to reflect the numbers, whether they describe population, health, literacy, or any of hundreds of other societal attributes. Under "Map Categories" select "Basic" for various population maps, including ones predicting the numbers for 2050 and 2300. The growth rate of global population has now slowed to about 1.15 percent per year, which may not seem high. But to get a sense of what that really means, go to "Understanding Exponential Growth," by Greg Bothun of the University of Oregon (zebu.uoregon.edu/2003/es202/lec06.html). Near the top of the page you'll find a link to a simulator where you can explore how population will affect greenhouse-gas emissions. At the bottom click on "next lecture" to learn more about the math of population dynamics.

As clever as our species is, we are not immune to many of the same physical restraints that keep other animal populations in check. Gigi A. Richard, a geologist at Mesa State College in Grand Junction, Colorado, ponders how many people the planet can ultimately sustain. Her startling conclusion: fewer than are alive today (www.ilea.org/leaf/richard2002.html). She cites biologist Dave Klein's classic study of the "carrying capacity" for reindeer on St. Matthew Island, Alaska. After the reindeer outstripped the island's food supply, their population simply crashed (see www.gi.alaska.edu/ScienceForum/ASF16/1672.html). Such ecological disasters culled human populations in the past; perhaps the most ominous example was the demise of the people of Easter Island (click on "Out of House and Home," also at the "World in the Balance" Web site, the first one listed above). Inevitably, part of the story of this century will be about how we come to grips with our "success."

ROBERT ANDERSON is a freelance science writer living in Los Angeles.



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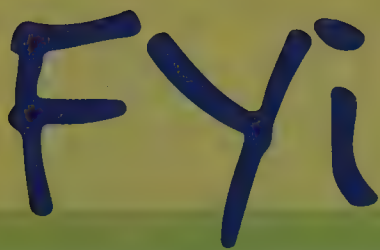
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Mercury is a morning object during April, but it has sunk too low into the bright morning twilight to be viewed from northern latitudes.

Venus, blazing at magnitude -4.1 , is the grand evening "star" this month, far outshining all the other stars and planets. It appears almost due west after sunset every night; look for it during and after twilight. If you watch carefully this month, you'll notice that the planet rises a little higher with each passing week, staying up from one and a half to almost two hours after the end of evening twilight. If you see a weird bright light hanging like some distant lantern low on the west-northwestern horizon as late as 10 or 11 P.M. local daylight time (LDT), it's only Venus.

Throughout the month Venus remains at nearly the same place above the horizon at dusk, while the stars in the background seem to slide behind it. On the evening of the 11th the planet's brilliant light hangs about two and a

half degrees to the left of the Pleiades. The dim, $+4.4$ -magnitude star 37 Tauri slips just a third of a degree (less than the diameter of the full Moon) south of Venus on the 15th, and the orange, first-magnitude star Aldebaran passes seven degrees below and to the left of Venus on the 21st.

Although small and gibbous, the planet is certainly worth a look in a telescope. Hunt it down in bright twilight or even in daylight, while it's still high in the sky. The best telescopic views of Venus are in a bright sky.

Mars rises south of east about two hours before sunup, and hangs nearly motionless above the east-southeastern horizon all month at dawn. Meanwhile, the faint stars of Aquarius slide behind the Red Planet and toward the upper right. Shining at magnitude $+1.1$ at midmonth, Mars in a telescope is disappointingly tiny. On the morning of the 29th, try using Mars as a guide to find the planet Uranus. Mars passes just 0.7 degree south

of that distant world. In binoculars or through a small telescope, Uranus appears as a dim, tiny "star" at magnitude $+5.7$, with a greenish-blue tint, only about 0.01 as bright as Mars.

Jupiter rises in the southeast, about ten degrees to the left of the bright ruddy star Antares, just before 1 A.M. LDT at the beginning of the month, and just before 11 P.M. at month's end. Telescopic observers can catch Jupiter at its highest in the south shortly before the beginning of morning twilight. The four largest moons of Jupiter can readily be seen with a small telescope or even through steadily held binoculars. The moons take from about two to seventeen days to orbit Jupiter, visibly changing their relative positions from hour to hour and from night to night. On the morning of the 23rd, for instance, you can see two moons on each side of Jupiter, whereas on the morning of the 28th, all four appear lined up on one side of the planet.

As twilight falls, **Saturn** emerges close to the meridian at magnitude $+0.3$, and remains visible well past midnight. The planet lies in the constellation Leo, the lion, all month, appearing some two and three-quarters times as bright as the first-magnitude star Regulus, glimmering about a dozen degrees east of Saturn. Any telescope that can reveal Saturn's rings can also show its 9th-magnitude moon Titan, which is always within four ring-lengths of the planet. Titan circles Saturn once every sixteen days. Look for it to the east of Saturn around the 4th and the 20th, and to the west around the 12th and 28th. As darkness falls on the evening of the 24th, a waxing gibbous Moon passes above and to the right of Saturn.

The **Moon** is full on the 2nd at 1:15 P.M. Our satellite wanes to last quarter on the 10th at 2:04 P.M. and to new on the 17th at 7:36 A.M. The Moon waxes to first quarter on the 24th at 2:36 A.M.

Unless otherwise noted, all times are eastern daylight time.

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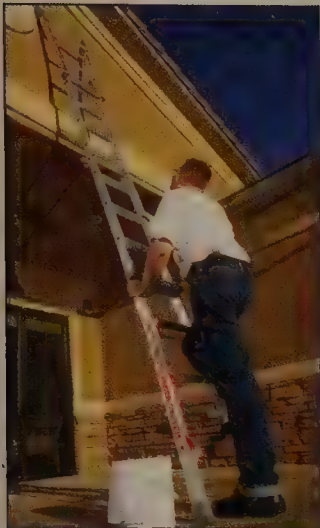
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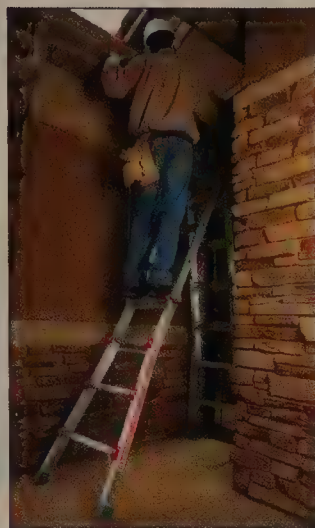
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In one of the most dramatic sequences, a *Velociraptor* and a *Protoceratops* die locked in combat, claws and jaws grasping at each other, as a sand dune sweeps over them, literally stopping them in their tracks until, after millions of years, erosion exposes their skeletons for scientists to discover. In another animation, the massive, long-necked sauropod *Seismosaurus* thunders about, its 110-foot-long body a vivid contrast to the



more diminutive Triassic dinosaurs also shown on screen.

Over the course of the film, viewers follow AMNH paleontologists past and present from the exotic expanses of Mongolia's Gobi Desert to the sandstone buttes of New Mexico tracing some of the greatest dinosaur finds in history. Included is beautifully preserved footage from the 1920s of

scientist and adventurer Roy Chapman Andrews, believed to be the inspiration for the fictional character Indiana Jones, on his seminal expeditions to the Gobi, where he and his team found hundreds of dinosaurs remains, including the first *Velociraptor*, the first dinosaur nest with eggs, and fossils of mammals that lived alongside the dinosaurs.

Fortunately, Andrews took along a Hollywood cameraman, and his rare early footage, juxtaposed against the IMAX-formatted footage of recent expeditions by AMNH paleontologists Mike Novacek and Mark Norell, provides audiences with a unique perspective on the field of paleontology over time.

IMAX films at the Museum are made possible by ConEdison.

An Elegant Gallery Reopens

As a rule, it is the contents of an exhibition hall that merit public attention. This month, however, the Museum celebrates not only the opening of a fascinating art show, but the reopening of the display space itself, the beautifully restored Audubon Gallery on the Museum's fourth floor.

The 3,000-square-foot gallery has been painstakingly refurbished, perhaps even surpassing its original 1930s glory. Double doors open to a serene rectangular hall, with 19-foot coffered ceilings graced by eight exquisite lamps, their large bowls trimmed with metal silhouettes of terns in flight. The inner doors, moldings, and wainscoting have been refinished and the walls covered in a cream linen that was chosen based on remnants of the original fabric. New

lighting also subtly complements the room's architectural details, which include magnificent marble moldings.

John James Audubon is, of course, famous for his bird paintings. However, the inaugural exhibition, *Unknown Audubons: Mammals of North America*, features more than 50 vivid depictions of mammals, along with artifacts such as books, Audubon's guns, and select taxidermy. Most of the mammal images appeared in the naturalist's last great work, *The Viviparous Quadrupeds of North America*, completed with the help of his two sons, John Woodhouse Audubon and Victor Gifford Audubon, and their father-in-law, the Reverend John Bachman, who wrote much of the text.

Once the repository of works by Audubon and such celebrated wildlife



C. CHESEK/AMNH

painters as Louis Agassiz Fuertes, Joseph Wolf, and Francis Lee Jaques, the original Gallery was designed by the architectural firm Trowbridge and Livingston, best known for its 1935 plan for the then brand-new Hayden Planetarium, as well as such New York landmarks as the B. Altman Building and the St. Regis Hotel.

AMNH and the Invisibles

We tend to think of all things microbial as agents of disease. But there are countless unseen organisms that are beneficial, even crucial, to sustaining human life. And yet much remains unknown about their numbers, the role they play in the ecosphere, and the possible threat posed to their existence by environmental change.

With a view to raising the profile of these essential microorganisms, scientists will gather on April 26 and 27, for the Center for Biodiversity and Conservation's 12th annual symposium: *Small Matters: Microbes and Their Role in Conservation*. The two-day symposium represents a significant interdisciplinary initiative, offering one of the first opportunities for microbiologists and conservation practitioners—from biogeochemists to wildlife managers—to come together to explore the intersec-

tion between microbe diversity and conservation. Presentations and panel discussions will address how this “unseen majority” profoundly affects the fate of all other life on Earth, the extent to which conservation practices do or don't take microbial life into account, and more.

On the evening of April 26, the general public is invited to join the scientific audience for the 2007 Mack Lipkin Man and Nature lecture, *Save the Microbes, Save the World: The Fate of Microbial Life on a Changing Planet*. NPR's Julie Burstein, *Studio 360*, leads a discussion on the importance of microbes as they relate to human health, biodiversity conservation, global climate change, early life on Earth, and even astrobiology.

Please call 212-769-5200 or visit <http://cbc.amnh.org> for details.

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Now you can take a personal tour of the Museum's special exhibition *Gold* with one of its curators. First, download a free podcast to your own portable player, then follow along with James D. Webster, Curator and Chairman, AMNH, Department of Earth and Planetary Sciences, as he walks and talks his way from case to case, exploring the history of this much-coveted precious metal.

This *Gold* tour, complete with images, is made available through an ongoing collaboration between the American Museum of Natural History and Science & the City, the online newsletter of the New York Academy of Sciences. Just visit www.amnh.org/podcast, where you will find the *Gold* tour with Dr. Webster as well as downloads of lectures by noted scientists and authors on a variety of subjects including the *Gold*-related Volcanic Activity and Formation of Gold Deposits.



The “Boot of Cortez,” the largest gold nugget found in the Western Hemisphere, weighs over 26 pounds.

PEOPLE AT THE AMNH

Karen Newitts

Visual Manager, Retail and Licensing



D. FINNIN/AMNH

If there's anything cooler than having an aunt who works at the American Museum of Natural History, it's having an aunt who works in the Museum's gift shops.

All five nieces and nephews got gifts from the Museum this Christmas, and at this writing a newborn sixth nephew was about to be surprised with his first pair of “little leather dino booties.”

Karen's job is to establish the “look, feel, and style” of the shops, periodically adjusting the displays to keep them fresh, and designing themed shops for special exhibitions. She helped create the Gold Shop, and is hard at work on upcoming shops.

She came to the Museum eight years ago after a series of retail jobs that were fun but didn't speak to her deep love of nature, which she traces to family summers in Maine, reading *Ranger Rick* magazines as a child, and watching television. “All my life I watched the nature channels, the PBS's.”

Passionate about the sea, Karen commutes nearly two hours each way from Long Branch, New Jersey, where she lives 20 seconds from the beach with her husband, Gary, a visual designer turned paramedic.

Quick to point out that 100 percent of shop profits go to supporting Museum education and research, Karen says of her job, “It's a feel-good. I love that. These are all gifts that give.” And she knows she's done that job well when, walking through a shop, she overhears a visiting adult or child exclaim, “I have to have it!”

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This glittering exhibition explores the captivating story of the world's most desired metal. Extraordinary geological specimens, cultural objects, and interactive exhibits illuminate gold's timeless allure.

Gold is organized by the American Museum of Natural History, New York (www.amnh.org), in cooperation with The Houston Museum of Natural Science. This exhibition is proudly supported by The Tiffany & Co. Foundation, with additional support from American Express® Gold Card.

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Beyond

Opens April 14, 2007

Exquisite images from unmanned space probes take visitors on a journey through the alien and varied terrain of

our planetary neighbors.

The presentation of both *Undersea Oasis* and *Beyond* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

GLOBAL WEEKENDS

International Earth Day

Sunday, 4/22, 1:00 p.m.

Native American song, Japanese drumming, and a presentation of dramatic photographs celebrate our connection to nature.

Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, the New York City Council, and the New York City Department of Cultural Affairs.

Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

LECTURES

The Natural History of the Bible

Tuesday, 4/10, 7:00 p.m.

Daniel Hillel discusses how Israel's land and water resources have changed since biblical times.

The Wild Trees

Thursday, 4/12, 7:00 p.m.

Richard Preston evokes the majesty of one of nature's greatest works, the coast redwood.

Marine Mythology

Tuesday, 4/17, 7:00 p.m.

Richard Ellis shares intriguing myths and legends about "monsters" of the deep sea.

Art/Sci Collision:

Of Human-Robot Bondage

Wednesday, 4/18, 7:00 p.m.

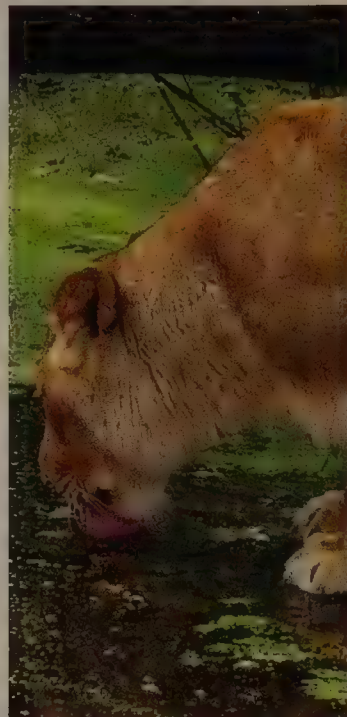
A panel considers how the emerging reality of human-machine relationships affects our understanding of ourselves.

This program is made possible, in part, by the Allaire Family and Ruth A. Unterberg.

Cats of Africa

Thursday, 4/19, 7:00 p.m.

This presentation explores behaviors of wild cats and reveals how new techniques in molecular genetics are helping conservation efforts.



Treasures of the Past

Tuesday, 4/24, 7:00 p.m.

AMNH Curator Peter Whiteley and Margaret A. Wood showcase the Museum's Southwest Native American collection and discuss craft traditions and contemporary interpretations.

Adventures in the Global Kitchen: The Incredible, Edible Dandelion

Tuesday, 4/24, 7:00 p.m.

Learn about the dandelion with Anita Sanchez. Program includes recipes and dishes to taste.

WORKSHOPS

Spring Bird Walks in Central Park

Eight-week sessions begin on

4/10, 4/11, and 4/12.

Visit www.amnh.org for details.

Observe the spring migration of birds in Central Park with Museum naturalists.

Animal Drawing

Eight Thursdays, 4/12–5/31

7:00–9:00 p.m.

The celebrated dioramas, dinosaur skeletons, and other distinctive features of the Museum are the setting for an intensive after-hours drawing course.

Reading Your DNA

Three Thursdays, 4/26–5/10

7:00 p.m.

Participants will make their own DNA "fingerprints" in this hands-on workshop.

FAMILY AND CHILDREN'S PROGRAMS

Identification Day

Saturday, 4/14, 1:00–4:00 p.m.

Bring in your favorite backyard finds, basement curios, and flea market discoveries for Museum scientists to attempt to identify.

This program is made possible, in part, by an anonymous donor.



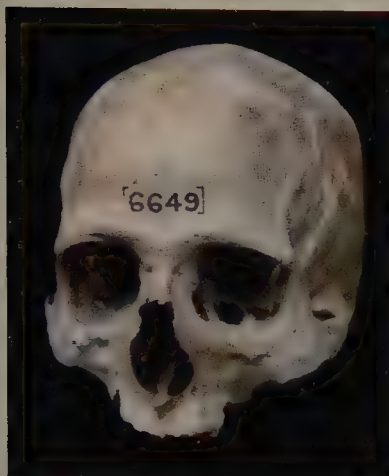
ROSE CENTER FOR EARTH AND SPACE

Sets at 6:00 and 7:30 p.m.

Friday, April 6

Visit www.amnh.org for lineup.

The 7:30 performance will be broadcast live on WBGO Jazz 88.3 FM



HUMAN ORIGINS

SATURDAYS

Secrets of Skulls

Saturday, 4/14

11:00 a.m.–12:30 p.m.

(Ages 8–10, each child with one adult)

1:30–3:00 p.m. (Ages 10–12, each child with one adult)

Compare skull casts of early humans.

Discover DNA

Saturday, 4/21

11:00 a.m.–12:30 p.m. (Ages 8–10, each child with one adult)

1:30–3:00 p.m. (Ages 10–12,

each child with one adult)

Kids and their parents can isolate their own DNA.

NEW! Alien Workshop

Saturday, 4/28

11:00 a.m.–12:30 p.m. (Ages

4–5, each child with one adult)

1:30–3:00 p.m. (Ages 6–7, each child with one adult)

Children will participate in astrobiology experiments and take home their own “alien.”

AMNH ADVENTURES

SPRING CAMPS

Monday–Friday, 4/2–6

9:00 a.m.–4:00 p.m.

Each weeklong session includes hands-on investigations, behind-the-scenes tours, and visits with Museum scientists.

Fossils and DNA

(For 2nd and 3rd graders)

Destination Space:

Astrophysics

(For 4th and 5th graders)

CENTER FOR BIODIVERSITY AND CONSERVATION

12TH ANNUAL SPRING SYMPOSIUM

Small Matters: Microbes and Their Role in Conservation

Thursday and Friday, 4/26 and

27, 9:00 a.m.–5:00 p.m.

See p. 61.

THE MACK LIPKIN MAN AND NATURE LECTURE

Microbes: Can't Live With 'Em, Can't Live without 'Em

Thursday, 4/26, 7:00 p.m.

See p. 61.

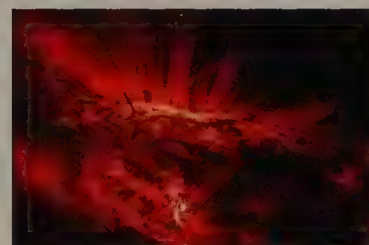
HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe

Neighboring Stars (and Planets)

Tuesday, 4/3, 6:30–7:30 p.m.



A sunspot

Celestial Highlights

Now Starring in Our Evening Sky: Venus

Tuesday, 4/24, 6:30–7:30 p.m.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions

Journey into deep space—well beyond the calm face of the night sky—to explore cosmic collisions, hypersonic impacts that drive the dynamic formation of our universe. Narrated by Robert Redford.

Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum. Made possible through the generous support of CIT. *Cosmic Collisions* was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

SonicVision

Fridays and Saturdays, 7:30 and 8:30 p.m.

Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamscape.

Presented in association with MTV2 and in collaboration with renowned artist Moby.

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m.,

or visit www.amnh.org. A service charge may apply.

All programs are subject to change.

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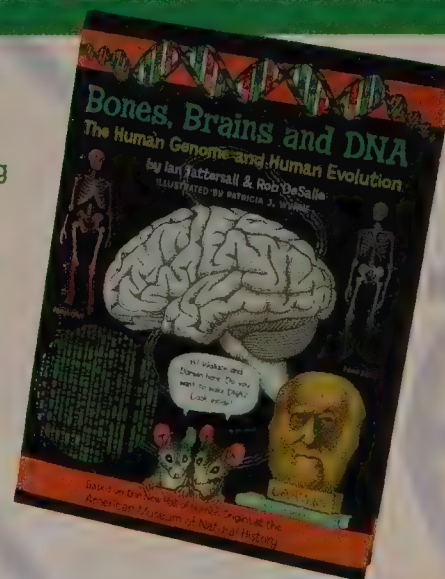
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Kids, Meet Your Relatives

Written by two AMNH curators, Ian Tattersall and Rob DeSalle, and celebrating the opening of the Spitzer Hall of Human Origins, this book introduces young readers to the most up-to-date approach to evolutionary science. Delightfully illustrated by Patricia J. Wynne. Age 8 and up.

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MUSEUM SHOPS

THERAPY: THE COSMIC PERSPECTIVE

BY DOLLY SETTON



NARCISSISM: THINKS WORLD REVOLVES AROUND IT



OCD: ALWAYS TRYING TO REMOVE SPOT

MULTIPLE UNIVERSES

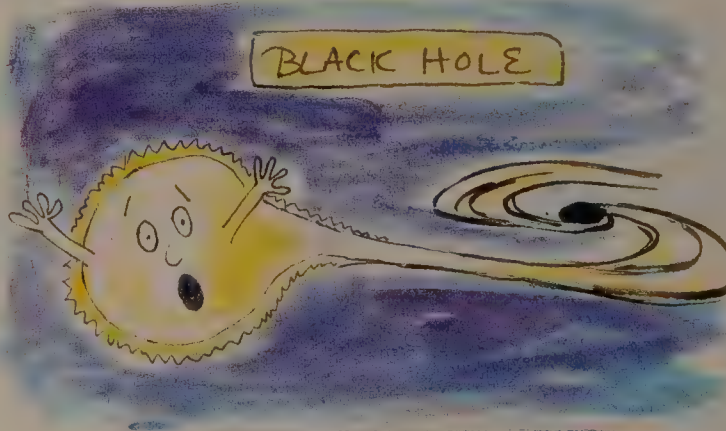


MULTIPLE PERSONALITY DISORDER



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GODFATHER COMPLEX

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Admission for Pavilion of Wings is not included in regular Museum admission. Prices are \$3 for adults, \$2 for students and seniors, and FREE for Museum Members and children under 5. Tickets are sold for entry on the half-hour starting at 10:00am. The last tickets are sold at 4:00pm.

STAND IN AWE? YES.
FOLLOW IN HIS FOOTSTEPS?
NOT RECOMMENDED.



Ed Viesturs was hailed by National Geographic as one of the strongest high-altitude mountaineers on Earth. He has gazed from the summit of Mount Everest six times, and climbed all 14 of the world's 8,000-meter mountains, without supplemental oxygen, a feat few people will ever accomplish. There are exceptional explorers on this planet - but only one Ed Viesturs.



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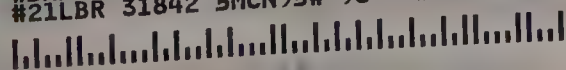
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TRACKING THE
ELUSIVE JAGUAR

Kicking back in nature's luxurious playground.

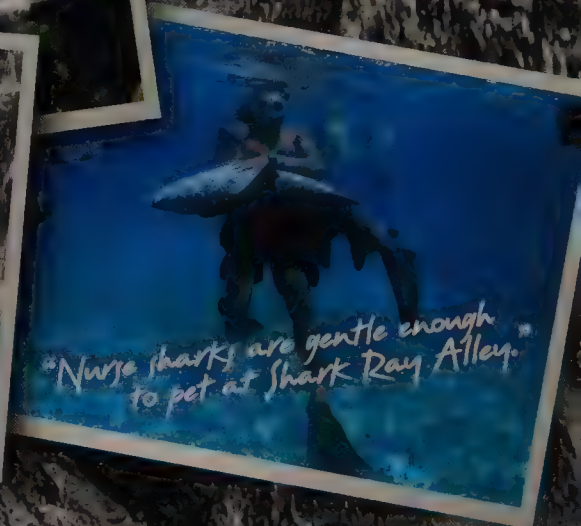
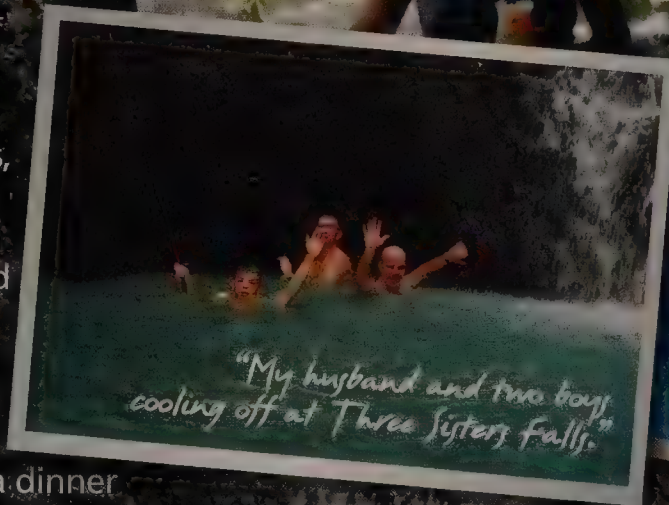
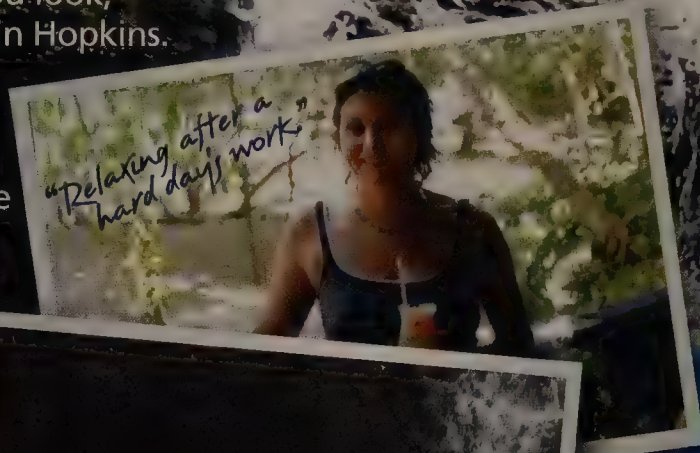
"One minute we're in a gorgeous resort, Belizean hardwood everywhere you look, tucked away on a secluded beach in Hopkins. The next minute we're in a tropical rainforest where nothing has changed in maybe a couple of million years. Our first day in Belize we hiked a trail through the rainforest, then set out on a serious climb that ended at a waterfall that was cold, pure, refreshing heaven.

That night we dined at Innie's, a local restaurant where the whole Innie family served as hosts. We bantered back and forth with the family (we later found out the whole country pretty much speaks English), and at the same time managed to demolish a dinner of exquisite beef and fresh seafood. So much for roughing it!

Next it was on to Shark Ray Alley where we swam with the stingrays and nurse sharks. My two teenaged boys had a ball!

We love the feeling we get being close to nature. Belize lets you do this in a very civilized way."

— Nora Campisi —



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THE
WATERS
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BELIZE

NATURAL HISTORY

MAY 2007

VOLUME 116

NUMBER 4



FEATURES

COVER STORY

30 TRACKING THE ELUSIVE JAGUAR

When you're following one of the Western Hemisphere's biggest cats, be aware that one might be following you.

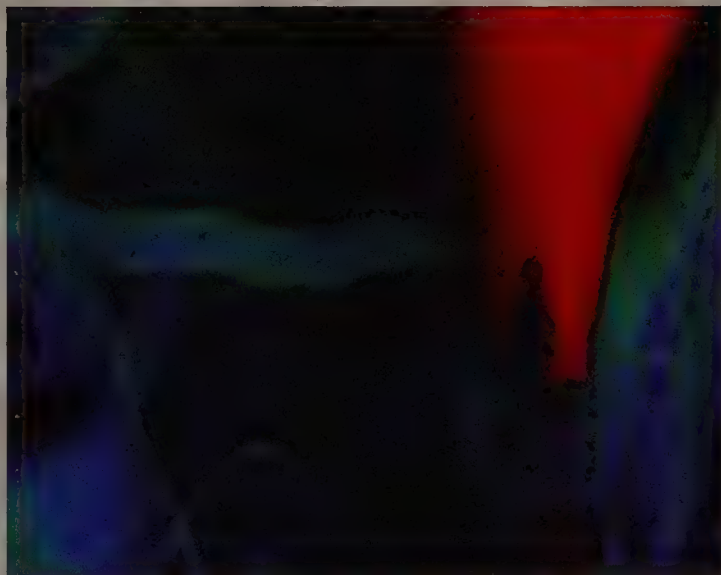
EDUARDO CARRILLO



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Evidence of animal and possibly human sacrifice suggests that burials at Tell Umm el-Marra were those of Bronze Age royalty.

GLENN M. SCHWARTZ



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What keeps a mother's immune system from treating her baby as foreign tissue? A new theory resolves the paradox.

GIL MOR

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Beanie Baby
*Photograph by
Dennis Kunkel*

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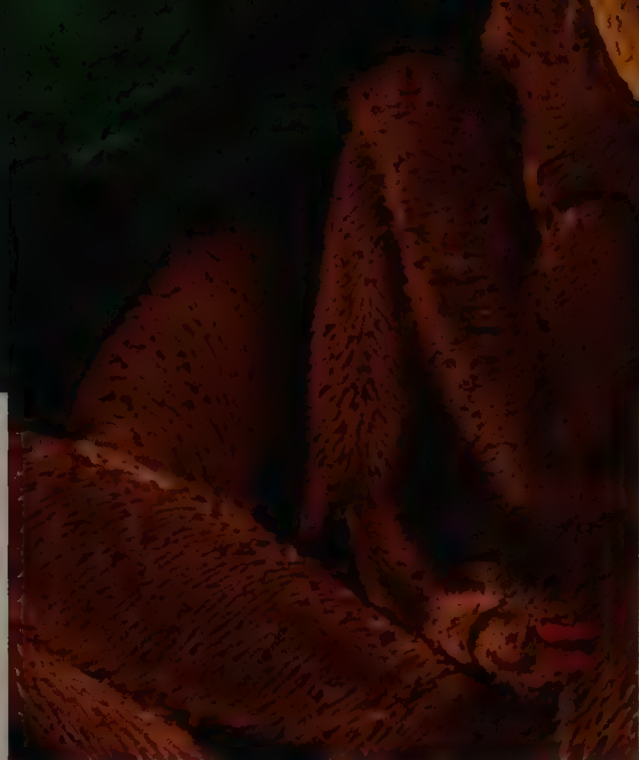
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www.naturalhistorymag.com



IF THERE WASN'T AN OFFICIAL
POLAR GRAND SLAM,
THERE IS NOW.

On February 3rd, 2006, Rune Gjeldnes arrived in Victoria Land, finishing his conquest of skiing solo across Antarctica, from Queen Maud Land via the South Pole. After traversing 4,804 kilometers of the Earth's most inhospitable landscapes, he became the world's first explorer to cross Greenland lengthways, the North Pole ice cap and Antarctica on skis unaided. Congratulations, Rune. The world is yours, from top to bottom.



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A close-up photograph of a brown, textured beanie baby toy. The toy has a fuzzy, knitted appearance with a pattern of small, dark brown spots. It is positioned on the right side of the frame, with its head and one arm visible. The background is a dark, mottled green, creating a naturalistic setting. The lighting is soft, highlighting the texture of the toy.

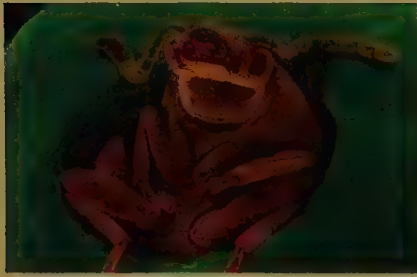
THE NATURAL MOMENT

Beanie Baby

Photograph by Dennis Kunkel



◀ See preceding two pages



Ready to plant his spring vegetable garden, Dennis Kunkel rooted out a packet of bean seeds, half-used from the year before. On pouring out the remaining seeds, though, Kunkel noticed they were covered in powder and pocked with round holes. Weevils—he was sure of it! A magnifying lens confirmed that a few straggling adults—each about four millimeters long—were squeezing out of the tiny holes. On impulse, Kunkel dunked the occupied seeds in preserving alcohol.

The common bean weevil (*Acanthoscelides obtectus*) starts life as an egg, strategically laid on a bean seed or a bean pod. When the weevil hatches, as a pale larva, it instinctively worms its way inside the nearest bean. There the weevil eats for several days before pupating. Unlike many other weevils, *A. obtectus* doesn't require extra moisture and thrives on dry beans in storage. Eventually it emerges from its tunnel with a new body, all set to find a mate.

Kunkel was lucky, he said, because one weevil—the one pictured here—got stuck inside its home bean. Kunkel dried and mounted the entrapped weevil for its portrait under the scanning electron microscope. He then added color to a black and white image, here magnified about 90×. This weevil, trapped by gluttony in its escape hatch, was the only one captured on film—all its slimmer companions came out in the alcohol wash.

—Erin Espelie

Muzzling Scientists

As a big fan of natural history, I follow the science of nature the way a baseball fan follows baseball. I'm thrilled to learn that jaguars, in some places, are making a comeback ("Tracking the Elusive Jaguar," by Eduardo Carrillo, page 30). I'm fascinated by the new findings about how a mother's immune system reacts to the "challenge" posed by her newly implanted embryo ("Pregnancy Reconceived," by Gil Mor, page 36). And I'm riveted by the creepy signs of human sacrifice in a complex of tombs, sealed for more than 4,000 years, that archaeologists have recently unearthed ("Hidden Tombs of Ancient Syria," by Glenn M. Schwartz, page 42).

In other words, I'm a happy fan whenever I can watch the exceptionally gifted players—the scientists—who play my favorite game. But I bristle when someone tries to play politics with the players. Here is what's going on inside an agency, the U.S. Fish and Wildlife Service (FWS), that deals with some of the topics closest to the hearts of readers of *Natural History*.

According to *The New York Times*, and confirmed by FWS officials, an internal memorandum circulated to its Alaska division in early March instructed agency staff not to publicly discuss climate change, polar bears, or the status of sea ice, unless specifically authorized to do so. Let's be fair: if you're an FWS scientist, the ruling applies to you only if you want to travel to an international meeting; then you'll have to sign a document that you understand "the administration's position" on those three issues, and that you "will not be speaking on or responding to" them. The *Times* quoted H. Dale Hall, the director of FWS, as saying that the new policy was "consistent with staying with our commitment to the other countries to talk about only what's on the agenda."

Now when scientists *do* science—when they play their game—they debate passionately and disagree openly, often with brutal honesty toward party lines, sacred cows, or other people's feelings. In short, they express themselves. So if you were, say, an FWS biologist invited to an international meeting, you might expect to be asked for, and should be prepared to give, a candid scientific assessment of issues within your expertise. You might even suppose there would be little point in spending taxpayers' money to send you to the meeting if you were barred from responding to such requests. On both suppositions, you would be wrong.

Unfortunately, the Fish and Wildlife fiasco is no isolated instance. For a review of the recent history of political agendas running roughshod over science, see the report on the Web (http://ncac.org/science/political_science.pdf) by the National Coalition Against Censorship. The principle should be clear: telling scientists—on the government payroll or not—that they can't express *scientific* findings in their own words, is not only a gag on free speech, as NCAC argues; it's also a perversion of the scientific enterprise.

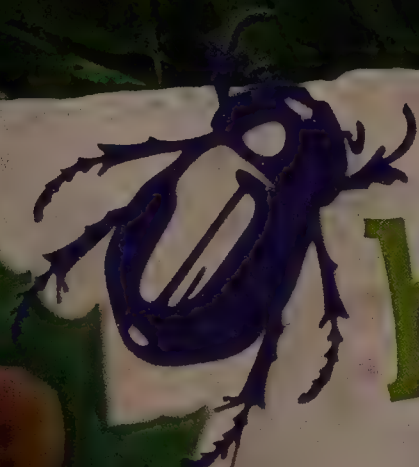
• • •

With this issue, I'm delighted to welcome Olivia Judson to *Natural History* as the author of a new column about all things biological, titled "Life Zone." Judson is a research fellow in biology at Imperial College London, and the author of a best-selling book, *Dr. Tatiana's Sex Advice to All Creation*. Her inaugural voyage, "A Terrible Scrooge," begins on page 22.

—PETER BROWN

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images, visit www.education.denniskunkel.com.

Formally a microscopist, **DENNIS KUNKEL** ("The Natural Moment," page 4), specializes in photographing what can't be seen with the naked eye. Neurons, spider silk, anthrax cells—all of them have become subjects of his images. Kunkel earned his doctorate in botany from the University of Washington in Seattle, then pursued an academic career at that university and at the University of Hawai'i in Honolulu. For more of Kunkel's



University of Massachusetts, Amherst. Carrillo has since taught at the Tropical Agricultural Research and Higher Education Center, in Turrialba, Costa Rica, and at the National University in Heredia, Costa Rica.

When **EDUARDO CARRILLO** ("Tracking the Elusive Jaguar," page 30) was growing up in San José, Costa Rica, in the early 1970s, he often visited the country's newly created national parks. There, he became enthralled with the wildlife, and went on to work as a field assistant in the parks, studying deer, peccaries, and small felines. Jaguars didn't formally enter Carrillo's studies until he won a Fulbright scholarship to pursue his doctorate at the

GIL MOR ("Pregnancy Reconceived," page 36) is an associate professor of obstetrics and gynecology at the Yale University School of Medicine. He is also the director of the Reproductive Immunology Unit and the Discovery to Cure Translational Research program at Yale. Mor's research focuses on the immunology of implantation, the role of apoptosis in tissue remodeling and reproductive cancer, and the role of inflammation in cancer formation and progression. He earned his doctorate in immuno-endocrinology from the Weizmann Institute of Science in Rehovot, Israel, and his M.S. and M.D. degrees from Hebrew University in Jerusalem. Mor is the editor of a recent book, *Immunology of Pregnancy* (Springer, April 2006).



A student of early civilizations and the way their rural and urban sectors interrelated, **GLENN M. SCHWARTZ** ("Hidden Tombs of Ancient Syria," page 42) has concentrated on the rise and fall of early complex societies in Syria. With a colleague, he is codirecting excavations at Umm el-Marra. Schwartz is Whiting Professor of Archaeology at the Johns Hopkins University. His books include *The Archaeology of Syria: From Complex Hunter-Gatherers to Early Urban Societies (ca. 16,000–300 B.C.)*, coauthored with Peter M.M.G. Akkermans (Cambridge University Press, 2003), and *After Collapse: The Regeneration of Complex Societies*, coedited with John J. Nichols (University of Arizona Press, 2006). Schwartz's article in this issue is based on work supported in part by the National Science Foundation (see grant credit in Picture Credits, below).

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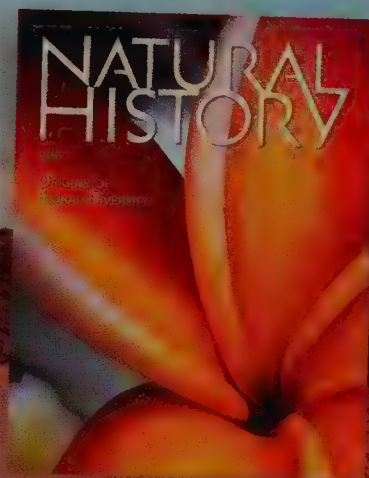
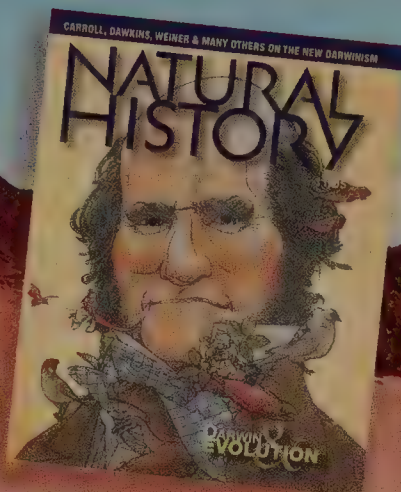
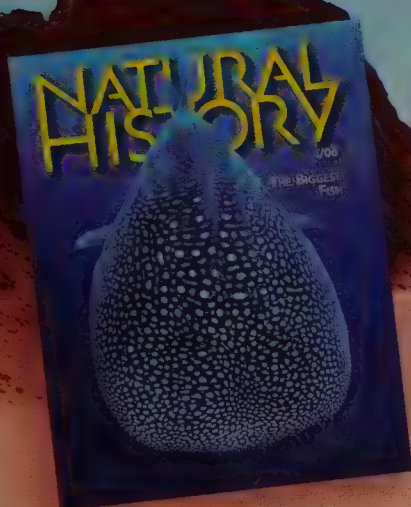
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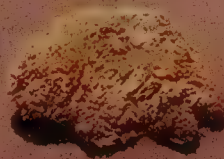
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**NATURAL
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LETTERS

Bear Watch

In "Bad News for Bears" [3/07] Bill Sherwonit has done a creditable job reporting on a complex controversy. The issue of hunting McNeil River bears just outside the sanctuary boundaries has been profiled by some as a pro-hunting versus anti-hunting confrontation. Nothing could be further from the truth. The tradition of ethical hunting runs strong and deep in Alaska, and hunting is managed well.

The point is that in the past few years a new form of wildlife appreciation and use has emerged—bear viewing. If wildlife and wild land are to persist into the future, they need the support of all user groups.

Nurturing the best place in the world to view brown bears (the McNeil River ecosystem) is a great way to accomplish that goal.

*Larry Aumiller
Missoula, Montana*

BILL SHERWONIT REPLIES:
As Larry Aumiller has probably since learned, and as others who read my article may be heartened to know, this past March 6 the Alaska Board of Game, reversing its decision of two years ago, voted unanimously to keep the Kamishak Special Use Area closed to brown-bear hunting.

Gas Bags

On reading Adam Summers's "Biomechanics" column "No Bones About

'Em" [3/07], it occurs to me that the largest cartilaginous fish species all lack air bladders. That may also help explain why sharks have cartilaginous skeletons: the only buoyancy organ they have is the oily liver, so they must do all they can to save weight. But why don't bony fishes, with their more effective buoyancy-regulating organ, reach the large size that the cartilaginous fishes do? Is a gas-filled bladder not enough to compensate for the heavier skeleton?

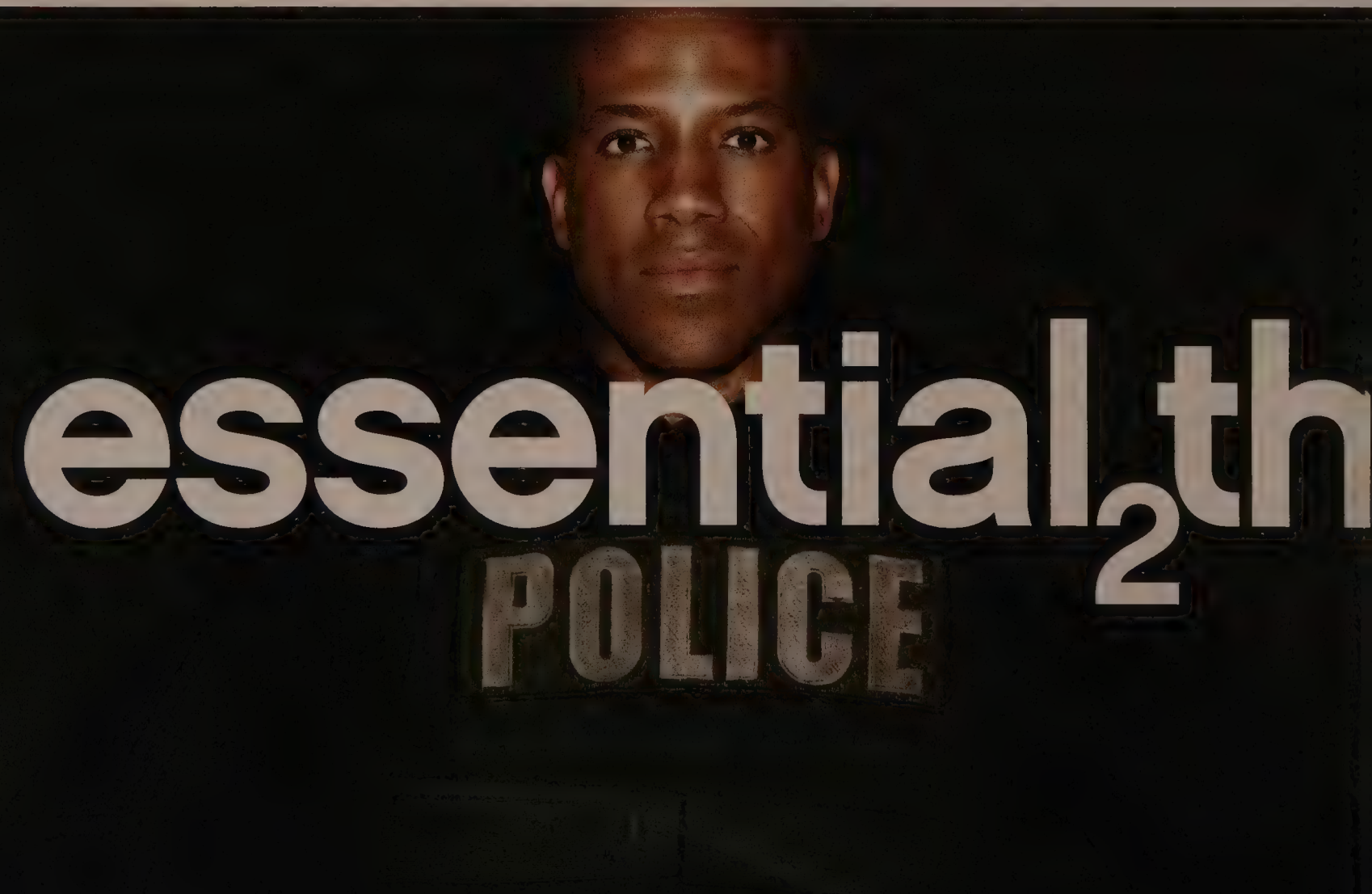
*Eriks Perkons
State College, Pennsylvania*

ADAM SUMMERS REPLIES:
An air bladder must scale with the cube of length—

just as the weight of the skeleton does—so larger fish species must carry around proportionately much bigger gas bags. The difficulty lies in maintaining the correct amount of air in a large bladder, because the gas compresses or expands with changes in depth. Either the fish would have to restrict its movements to one depth or orient itself completely to the surface. Some large freshwater fishes adopt the latter strategy.

Latrine Duty

Stéphan Reeb's "Sampling" titled "400-Yard Dash" [3/07] tells of recently discovered Dead Sea Scroll texts that describe the Essenes' practice of



essential, the
POLICE 2

defecating away from their settlements. The commandment for those sanitary acts was written centuries before the Dead Sea Scrolls, in Deuteronomy 23:12–14: “Designate a place outside the camp where you can go to relieve yourself. As part of your equipment have something to dig . . . a hole and cover up your excrement. For the Lord your God moves about in your camp. . . . Your camp must be holy, so that he will not see among you anything indecent. . . .”

Arthur Smilowitz
East Norwich, New York

JOE E. ZIAS REPLIES: Our article on which the “Sampling” is based mentions that the Essenes did

indeed base their rules on passages from the Bible. As it says in Ecclesiastes 1:9, “There is nothing new under the sun.”

**Brer Coyote
and Brer Badger**

Nick Atkinson’s “Sampling” about cooperative hunting by groupers and eels [“Double Trouble,” 3/07] states that cooperative hunting between species had previously been noted only among humans hunting with dogs or dolphins. But such behavior also occurs with coyotes and badgers. The badger, an excellent digger, pursues prey, such as prairie dogs, underground, while the coyote, a swift runner, patrols the surface, catching any

animals that try to flee. The strategy is often employed in times of drought, when prey is scarce.

I observed this behavior in Chaco Canyon, New Mexico, where I saw a badger flush a rabbit out into the path of the waiting coyote. After disposing of the rabbit, the two hunters sniffed noses, and ambled off down the road together. This encounter inspired my children’s picture book *Coyote and Badger: Desert Hunters of the Southwest*.
Bruce Hiscock
Porter Corners, New York

NICK ATKINSON REPLIES: The main thrust of Redouan Bshary’s findings was that examples of inter-specific cooperative hunt-

ing are exceedingly rare in organisms such as fishes, which are often regarded as lowly animals. Humans and birds have the neural processing power to organize a coordinated effort, but no one had suspected that fishes were capable of the same. Perhaps the most surprising aspect of the findings was the degree of collaboration, despite the indivisibility of the prey.

Natural History welcomes correspondence from readers. Letters should be sent via e-mail to nhmag@naturalhistorymag.com or by fax to 646-356-6511. All letters should include a daytime telephone number, and all letters may be edited for length and clarity.

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SAMPLINGS

Infection Selection

Not all parasites are created equal; biologists have struggled to explain why some are more contagious than others. One well-regarded theory suggests that parasites are most infectious when their hosts move around a great deal and come into frequent contact with one another. But when hosts roam less, highly infectious parasites soon find themselves surrounded by infected individuals, which limits their further advance. Under such conditions, parasites do well to become less infectious, thereby increasing the odds of encountering new victims. Michael Boots, an evolutionary ecologist at the University of Sheffield in the United Kingdom, and Michael Mealor have now corroborated the theory in an unusual experiment with breakfast cereal and virus-ridden, cannibalistic caterpillars.

In the laboratory, Boots and Mealor infected caterpillars—larvae of the moth *Plodia interpunctella*—with a virus that spreads naturally when an uninfected cat-

terpillar cannibalizes an infected one. They placed infected caterpillars among healthy ones in bins of food, a honey-sweetened cereal. Some caterpillars lived in dry, crunchy cereal and could mingle readily. The others lived in the same cereal, but moistened and sticky, which hindered their movement and reduced contact between them.

After forty weeks (about eight *P. interpunctella* generations) Boots and Mealor fed the viruses from each group to a fresh, healthy batch of caterpillars, then measured the rate of infection. Sure enough, viruses in slow-moving, gruel-dwelling caterpillars had evolved to be a third less infectious than the viruses in mobile, crispy-cereal caterpillars.

The results probably hold outside the cereal box, too. As extensive travel and trade bring people and wildlife into ever more frequent contact, parasite strains may become more infectious. (Science) —Corey Binns

Unbound by Fog

Navigating under clear skies is relatively straightforward, but the ancient Vikings sailed northern seas that are frequently shrouded in fog and clouds. Their sagas mention enigmatic “sunstones,” held aloft on

overcast days to locate the position of the Sun. Such sunstones could have been useful for navigation, but given their obvious romantic appeal, they may have been just literary inventions—none have ever been found. In 1967, however, the late Danish archaeologist Thorkild Ramskou pointed out that cordierite—a crystal common among pebbles on Norwegian coasts—changes color and brightness when rotated in polarized light. Cordierite stones, he suggested, might have enabled Vikings to perceive polarized light in the sky, from which they could reliably deduce the Sun’s position.

It’s possible to detect polarized light in patches of open sky; many insects rely on it

to find their way if the sun is invisible. It has been unknown, however, whether light that has passed through fog or clouds is strongly enough polarized—or makes an appropriate directional pattern across the sky—to serve as a sun compass. Now Ramón Hegedüs and his graduate adviser, Gábor Horváth, a biophysicist at Eötvös University in Budapest, and two colleagues have confirmed that foggy and cloudy skies at northern latitudes exhibit a polarization pattern similar to that of open skies.

That makes the use of sunstones plausible. Still, the polarized light under foggy skies is extremely weak; under cloudy skies it’s stronger, but whether cordierite (or another natural material, such as tourmaline or calcite) are sensitive enough to reveal it needs further study. For now, how Vikings navigated in gloomy weather remains obscure. (Proceedings of the Royal Society A)

—Stéphan Reeb

Missing Mass

The Plateau of Tibet is a geological puzzle. Comprising nearly 900,000 square miles and rising 16,000 feet above the surrounding terrain, it is the largest and highest plateau on Earth. It also has the thickest crust—at an average thickness of more than forty miles, the crust is double that of most landmasses. How did the plateau come into being? Geologists have floated numerous hypotheses over the decades, but strong evidence either for or against them has been sparse.

According to one hypothesis, when the Indian and Eurasian plates plowed into each other 55 million years ago, the Eurasian plate’s lithosphere (the outer crust plus an underlying layer) crumpled and pushed the Plateau of Tibet upward into being. Then, about 15 million years ago, a massive block of rock at least 60,000 square miles in area detached from the bottom of the Eurasian plate. As the rock sank, the plateau above it buoyed upward another mile, until it reached its present height.

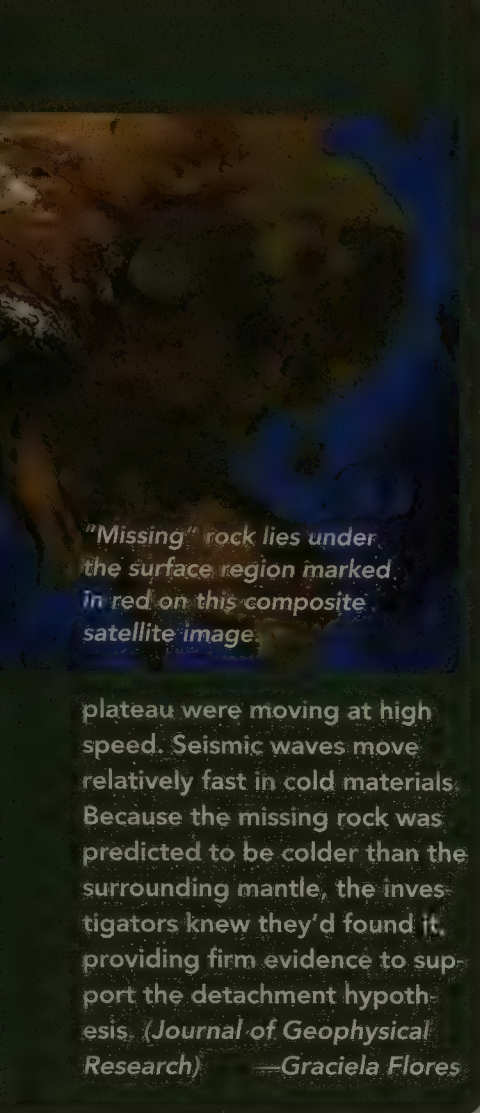
For decades, investigators

have been looking for signs of the sunken hunk of lithosphere without success. But recently Tai-Lin Tseng and her graduate adviser, Wang-Ping Chen, a geophysicist at the University of Illinois at Urbana-Champaign, demonstrated that the missing rock is just where everybody expected it to be, centered some 350 miles north of the border between Nepal and Tibet and 400 miles beneath the Earth’s surface.

Tseng and Chen made the discovery after collecting seismic signals from some 300 monitoring stations in India, Nepal, Tibet, and beyond, which indicated that seismic waves traveling beneath the



Viking ships, woodcut, 1879



"Missing" rock lies under the surface region marked in red on this composite satellite image.

plateau were moving at high speed. Seismic waves move relatively fast in cold materials. Because the missing rock was predicted to be colder than the surrounding mantle, the investigators knew they'd found it, providing firm evidence to support the detachment hypothesis. (*Journal of Geophysical Research*) —Graciela Flores

Family Ties

As any textbook of biology (or sex education) will tell you, inbreeding is a big no-no. But at least one species of fish apparently cannot read. A team of behavioral ecologists led by Timo Thünken at the University of Bonn in Germany has discovered that members of a species of cichlid, *Pelvicachromis taeniatus*, prefer to mate with their brothers and sisters. One possible reason: closely related parents do a better job of raising their young than unrelated parents do.

P. taeniatus is a colorful fish, between two and three inches long, that lives in the streams of Cameroon and Nigeria. Mom and dad cooperate to repel predators that attack their eggs and young fry.

When Thünken's team gave captive fish the choice of spawning with a stranger or with a sibling, three times as many chose the sibling. That was the case even though siblings were unfamiliar with each other because they had

been separated shortly after hatching. In the resulting pairs of inbreeders, males spent more time near their eggs and young and quarreled less with their mates than did males in outbreeding pairs.

Inbreeding among animals is rare because offspring are often severely handicapped by harmful, recessive genes. Yet both inbred and outbred fry in Thünken's experiments grew and survived equally well. The species may have few harmful recessive genes, in which case the genetic cost of inbreeding may be easily outweighed by the twin benefits of passing along all the genes shared with one's mate and providing one's offspring with two caring, cooperative parents. (*Current Biology*)

—S.R.

Water in the Bank

For wallabies in Australia's Northern Territory, putting a nose in the river often leads to a lot more than just a refreshing sip of water. In some areas, saltwater crocodiles (which can also live in brackish waters) are common, lying nearly submerged in the water to ambush the thirsty and unwary. But the agile wallaby has found a way to get a safer drink, according to a study by J. Sean Doody, an ecologist at the University of Canberra, and two colleagues. Not only do they visit the river at times of the day when the "salties" are relatively inactive; the cunning marsupials have also figured out that it's safer to dig a drinking hole in the riverbank than to sip from the river directly.

A shallow pit in the soil a yard or more away from the river



Watch a wallaby dig, mate!

quickly fills with water. By recording wallabies' behavior at the drinking holes with motion-sensitive cameras and studying footprint patterns on the riverbank, Doody found that they much preferred the holes to the river.

He also discovered that the wallabies appear to respond to variable risk: where the crocodiles were numerous, the wallabies sited their holes farther from the water's edge and dug them deeper than where the crocodiles were scarce. Wallabies, it seems, are happy to invest extra energy to avoid becoming a hungry reptile's dinner. (*Ethology*)

—Nick Atkinson

But Who's Gonna Read It?

Today's exploding volume of data resides on stacks of paper, reels of magnetic tape, piles of compact disks, or banks of silicon chips. But those media are fairly fragile and last, at most, a few thousand years. For truly long-term storage, something nearly indestructible is needed. A new study suggests an intriguing possibility: the DNA of bacteria.

Nozomu Yachie and his graduate adviser, Yoshiaki Ohashi, a molecular geneticist at Keio University in Tsuruoka, Japan, together with several colleagues, encoded the message " $E=mc^2$

1905!" in the DNA of *Bacillus subtilis*, a tough bacterium that lives in soil.

After

assigning the letters and symbols to specific sets of DNA nucleotides, they prepared coded nucleotide sequences, which they inserted into the genomes of bacteria. A few days—and numerous bacterial generations—later, they extracted the DNA and decoded the sequences to read the message.

Certain bacteria, including *B. subtilis*, form resistant spores that can revive after millions of years of dormancy. And living bacterial populations can survive for eons, too. Of course, their DNA can mutate, but the Japanese team developed a simple way to encrypt and store redundant—yet distinct—versions of the data. As the technology for replicating and sequencing DNA becomes cheaper, faster, and more accessible, bacterial DNA might someday replace the silicon chip.

(*Biotechnology Progress*)

—S.R.



Thin Skin

Oysters on the half shell are considered a delicacy, but what about mussels on the three-quarter shell? A new study shows that human emissions of carbon dioxide (CO₂) could reduce bivalves' ability to build their shells by as much as 25 percent.

In addition to warming the Earth, excessive CO₂ is making the oceans more acidic, which decreases the concentration of dissolved carbonate in seawater. Without carbonate for building their shells, numerous minute organisms—including corals and species of phytoplankton and zooplankton—are showing alarming signs of distress. Now Frédéric



Mussels

Gazeau, a marine biologist at the Netherlands Institute of Ecology in Yerseke, and several colleagues have shown that the phenomenon propagates up the food chain.

In the laboratory, Gazeau exposed mussels and oysters to water with various levels of CO₂ for periods of two hours, measur-

ing the water's average pH and the change in its alkalinity, which is proportional to its concentration of carbonate. From alkalinity levels he calculated the mollusks' rate of shell construction, or calcification. Sure enough, the higher the water's CO₂ concentration and the lower its pH, the slower the mollusks' calcification.

If atmospheric CO₂ reaches the levels expected by 2100, Gazeau predicts the calcification of oyster shells could decline

by 10 percent and that of mussel shells by a quarter. As the declines in calcification affect the development of juvenile shellfish, and as adults become more vulnerable to predation, both aquaculture and marine ecosystems are likely to

change. Gazeau stresses that his findings are preliminary; he measured only short-term responses to high CO₂ and low pH. But his next experiment will test their responses over several months. (*Geophysical Research Letters*)

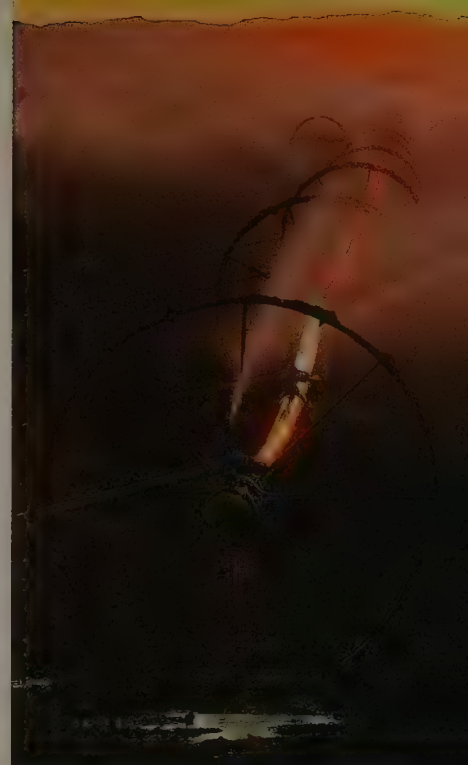
—Rebecca Kessler

Cool Acres

Irrigation might be cooling local climates, and in the process, hiding the true magnitude of global warming. Many temperature-monitoring climate stations happen to lie near irrigated agricultural land; new research shows that the temperatures measured there might be skewed downward, making the actual warming much higher than estimates show.

Lara M. Kueppers, an ecosystem scientist now at the University of California, Merced, and two colleagues ran a computer model to estimate what temperatures would have been in California between 1980 and 2000 if irrigated areas had not replaced natural vegetation. For comparison, they ran another model that made the estimate on the basis of actual land-use patterns in 1990.

On average, the team found, daytime high temperatures in summer were about thirteen Fahrenheit degrees cooler in the irrigated areas than they would have been if natural vegetation still covered the land. (Irrigation made little difference in night-



time or winter temperatures.) Irrigated farmland occupies 8 percent of California's land, causing the state's overall temperature to drop by slightly less than one degree. The cooling effect of irrigation probably stems from increased evaporation from soils and plant leaves on summer days.

The effects are almost certainly not limited to California. Around the world, more than 650 million acres are irrigated, and more than half the temperature-monitoring stations in at least one important global temperature dataset also lie in such areas. (*Geophysical Research Letters*)

—S.R.

Hot Time in the City

As the Earth warms, life in big cities is getting tougher. Abundant dark, sun-absorbent surfaces and heat emitted by cars and buildings, among other factors, push temperatures as much as twenty-two Fahrenheit degrees higher than those in the surrounding countryside. One way or another, people manage to avoid the excessive heat. But what about the rest of the urban fauna?

Michael J. Angilletta Jr., a thermal biologist at Indiana State University in Terre Haute, and a team of investigators argue that so-called urban heat islands are excellent natural laboratories for testing the possible effects of climate change on organisms. In many species, populations from warm habitats tolerate heat better and cold



Leaf-cutter ants

worse than populations from cooler climates. Angilletta and his colleagues predicted that the same would hold true for urban and rural populations of the leaf-cutter ant *Atta sexdens*.

To test the prediction, the investigators collected *A. sexdens* in the megacity of São Paulo, Brazil, and in rural areas nearby. Then they exposed the insects to a stressful

temperature of 108 degrees F. and compared the time it took the two groups to lose mobility. Finally, they chilled members of both groups for twenty minutes, then timed the ants' recovery. As predicted, the urban "Paulistanos" survived the heat 20 percent longer than their rural counterparts. But their greater heat tolerance came at no obvious expense of cold tolerance: both groups of ants recovered from "chill coma" in nearly identical times.

Angilletta and his colleagues can't tell whether the different responses of urban and rural ants come from genetic adaptations or are simply the result of physiological acclimatization. In either case, their study hints that ants, at least, might be able to beat the heat of a warming Earth. (*PLoS ONE*)

—G.F.

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PRINCE EDWARD ISLAND

Prince Edward Island is known as the birthplace of Canada and home of *Anne of Green Gables*, published almost 100 years ago. In *Anne's Land*, on the island's central north shore, miles of white sand beaches and fragile sand dunes are protected in Prince Edward Island National Park. Follow the Blue Heron Coastal Drive for views of red cliffs, open fields, and the rolling farmlands made famous in the novel.

The island's beaches are warm enough for summertime swimming, and a good way to explore them is by following the North Cape Coastal Drive along the western coast. Enjoy the serenity of a secluded beach or the bustle of a food festival starring the island's prized mussels, lobsters, and oysters. North Cape is the home of Canada's only national wind test site. Prince Edward Island now draws more than five per cent of its electricity from wind energy at the Atlantic Wind Test Site. View the gigantic windmills and learn all about the generation of wind energy in the newly expanded North Cape Interpretive Centre.

Start the drive in the small historic city of Summerside, with a concentration of nineteenth-century architecture and a summer-long Celtic festival. This small city is the only place in North America where you can earn a degree in bagpiping—at the College of Piping, a center of traditional Scottish music and dance. Prince Edward Island's tip-to-tip Confederation Trail passes nearby. Developed along abandoned rails, the trail crisscrosses wetlands, hardwood groves, and quaint villages and rivers, with opportunities for birdwatching along the way.

Follow Route 11 out of Summerside and head to la Région Évangéline, the heartland of Prince Edward Island's French culture. A short detour up Route 12 leads to the Acadian Museum in Miscouche, an introduction to the island's first French settlers, who arrived in 1720. Then time your arrival in Évangéline to coincide with lunch or dinner. Savor an exquisite Acadian lobster or take in some traditional Acadian fiddling and entertainment. From Woodstock, take Route 143 and turn south to O'Leary, where the Potato Museum celebrates Prince Edward Island's most famous export. The museum houses the largest collection of potato-related artifacts in the world. Continue south to Cedar Dunes Provincial Park, where the shore seems to stretch forever, particularly from the vantage point of the West Point lighthouse. Camp on the beach, follow a nature trail, head to the nearby wharf for fresh seafood. The drive west, finally leading to North Cape, is characterized by steep red cliffs, gentle beaches, and fishing boats in the distance.

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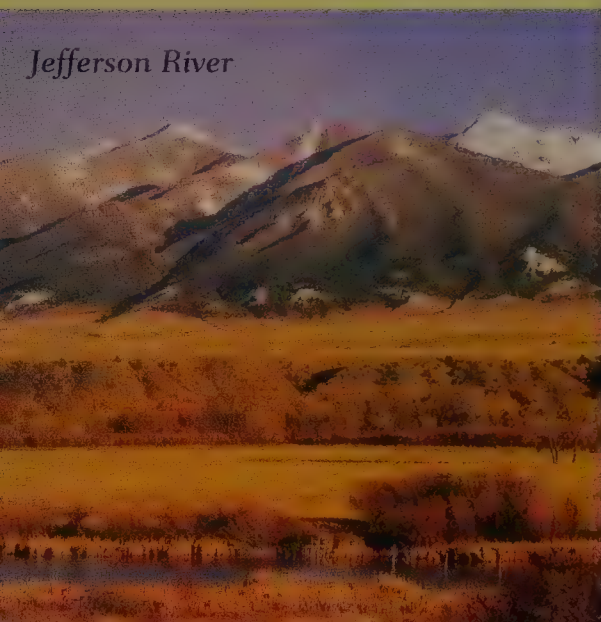


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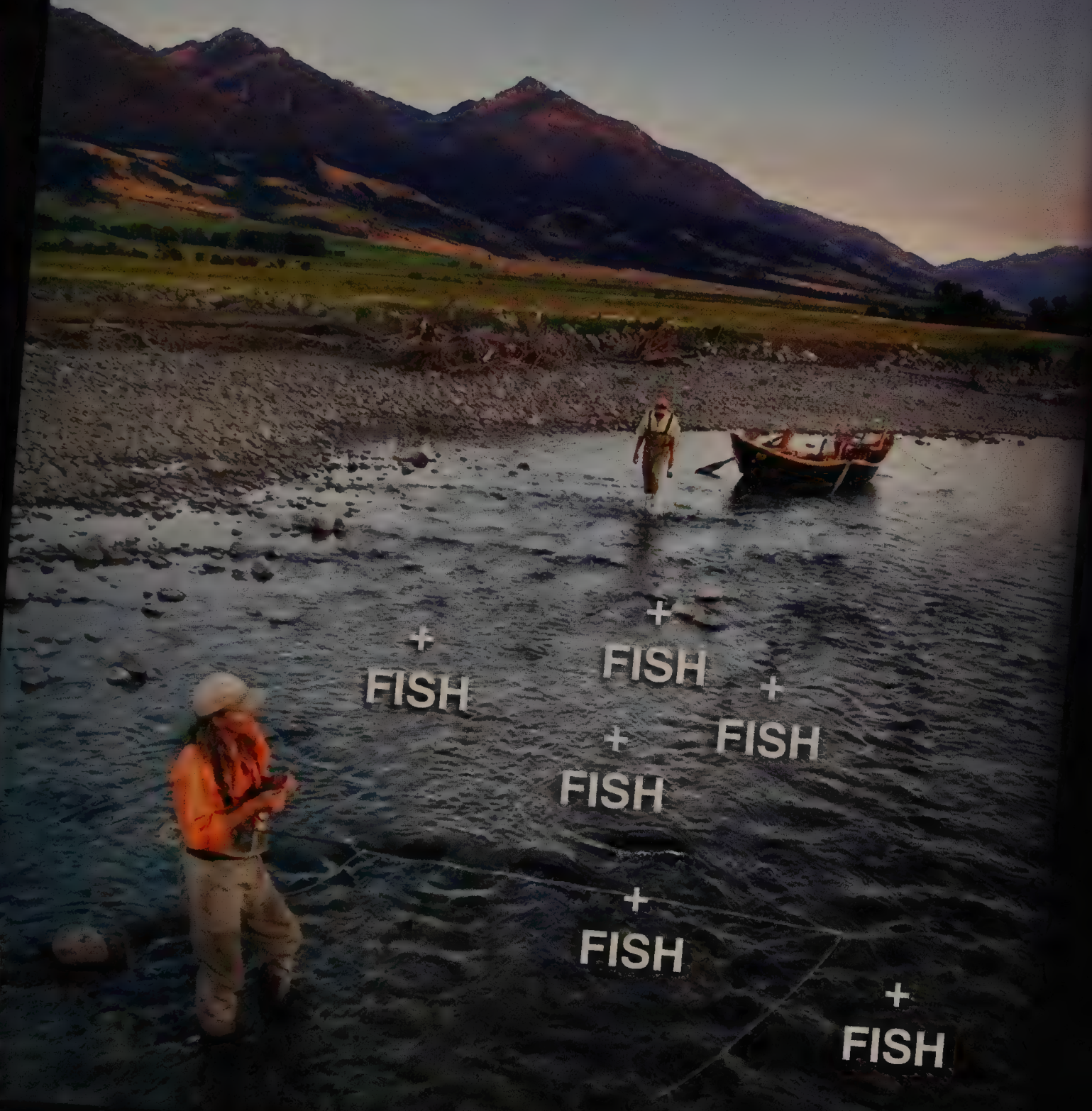
MONTANA

In northwest Montana, travel along Highway 83 from Seeley Lake to Swan Lake, where hundreds of lakes dot the narrow, densely forested valleys. Squeezed between the Mission Mountains and the Swan Range, this 91-mile drive offers everything from solitary hiking to golfing to canoeing. Three miles off 83, pick up the trailhead for the easy hike to Holland Lake Falls and Old Squeezer Loop, an excellent area for birding, or follow the willow-lined Clearwater River Canoe Trail for wildlife sightings (including bald eagles) from the water.

In Glacier National Park, take the popular fifty-mile Going-to-the-Sun scenic drive up to the crest of Logan's Pass, where you will cross the Continental Divide. Pullouts along the road provide views of large glacial lakes, cedar forests, and bare alpine tundra. Amid historic lodges and breathtaking scenery, you'll spot bighorn sheep and other grazing wildlife. In Yellowstone National Park, Firehole Lake Drive is a one-way side road about three miles long. It takes you to the cone-shaped White Dome Geyser and the Great Fountain Geyser (worth seeing for its nearly hour-long eruptions, about 100-150 feet high). If you're traveling between the two parks, Highway 89 and the Kings Hill Scenic Byway, takes you through the rugged beauty of the Little Belt Mountains and winds its way past pristine mountain lakes and streams, historic mines, and abundant wildlife-viewing opportunities.

Lewis and Clark spent much of their expedition in Montana, with nearly half their campsites in the state, and the National Historic Trail connects many of the sites they encountered during their 1805-1806 journey. Trail highlights in Missouri River Country, in the state's northeast corner, include the million-acre Charles M. Russell National Wildlife Refuge, the second-largest wildlife refuge in the lower 48; and Fort Peck Lake, with 1,500 miles of shoreline. You'll see the same landscapes experienced by Lewis and Clark, with an abundance of deer, antelope, elk, and enormous flocks of songbirds and raptors. The Northeastern Plains Birding Trail guides you to the best birding in the area, with details on species and habitats. Birdwatchers can head to the lakes, reservoirs, and mountains of Montana to see millions of migrating birds.

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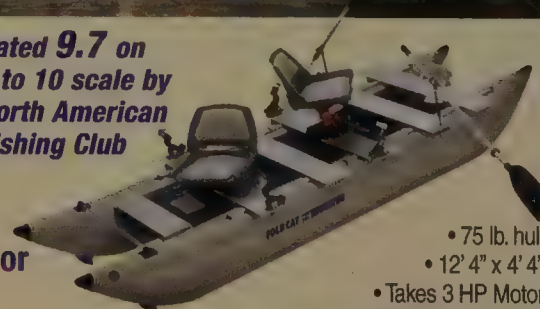
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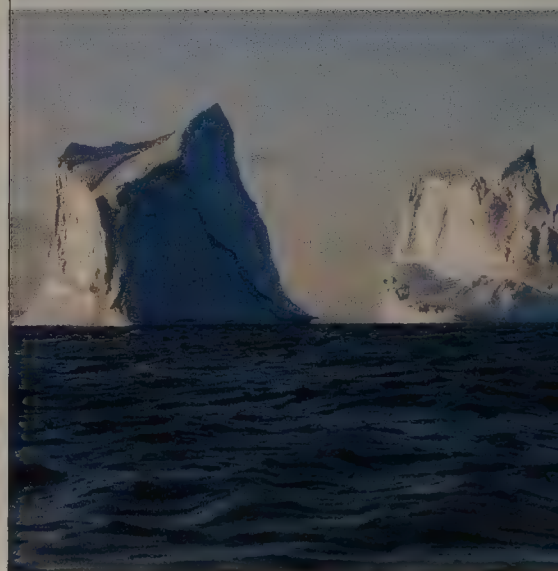
The southern portion of Gros Morne National Park, accessed along Route 431, part of the Viking Trail, is less frequented than the rest of the park. Those missing it are bypassing the geological wonder called The Tablelands that literally stands out amid the low, rounded mountains. That's because it's flat and orange. It looks like an escapee from the Badlands, but in fact was thrust from the earth's mantle eons ago by tectonic forces. Its surface is almost devoid of plants that find its weird chemistry too toxic to colonize. But it's great for a hike.

The Road to the Isles, or Route 340, is part of the Kittiwake Coast that takes you to the shore of Iceberg Alley on the northeast coast of the Island of Newfoundland. At Long Point Lighthouse in Twillingate, which overlooks the cool North Atlantic, 10,000-year-old bergs can be seen floating by. Boat tours to see icebergs are likely to encounter whales, as well. On the way from Twillingate, stop by the Prime Berth Fishing Museum for a taste of the life of a fisherman.

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A Terrible Scrooge

Nature is so cost-conscious that Darwinian principles apply even when cells are selecting the building blocks of proteins.

By Olivia Judson

Honeybees. Sea urchins. Black cottonwood trees. Those are just three of the species that had their genomes published last year. It's amazing to think that a dozen years ago, the sequencing of any whole genome was a sensational event. Back then, just a few viruses and one puny bacterium had had theirs done. Now DNA sequencing is almost as automated as sausage-making, and geneticists have whole-genome sequences for a menagerie that includes dogs, rice, humans, chimpanzees, roundworms, mosquitoes, chickens, silkworms, red algae, at least four species of fruit fly, scores of fungi, hundreds of bacteria, and hordes of viruses. More exciting still, whole-genome sequences for species that don't even walk the planet any more, such as the Neanderthal, the dodo, and the woolly mammoth, will soon be available.

Each genome is a treasure trove of surprise and revelation. Sea urchins turn out to have genes for a large and complicated immune system, which may explain why some of them manage to live well beyond their hundredth birthdays. A glance at the genome of trypanosomes—the single-celled parasites that cause sleeping sickness and Chagas' disease—shows why they are so good at evading the human immune system. About a quarter of their 12,000 genes is a disguise kit, the molecular equivalent of wigs, hats, sunglasses, and false mustaches. Just when the immune system knows

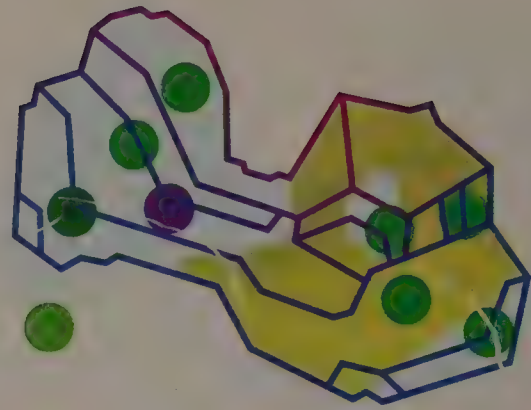
what it's looking for, the trypanosomes change their appearance.

But it's not just the individual genomes that are fascinating. It's the comparisons. Without comparisons, you don't know which attributes of a sea urchin are unique, which are shared by close relatives such as starfish, and which are common to all organisms, from bacteria to people.

More important, you can't detect evolutionary patterns and trends. It was only by comparing teeth from many different animals, from horses to the fruit-eating fish of South America, that anatomists learned that diet reliably affects the evolution of tooth shape. Only by comparing the genomes of parasitic bacteria with those of their free-living

relations did biologists discover that becoming a parasite has predictable effects on genome evolution. The genomes of the parasites are smaller and more streamlined than those of their free-living relatives. Which makes sense: if you live inside another organism, you don't have to bother much about finding food.

Indeed, it was by comparing everything, from the miniature males of certain species of barnacle to the beaks of the finches living in the Galá-



pagos Islands, that Charles Darwin discovered natural selection in the first place. In each generation, some organisms have more offspring than others. Some offspring die before they make it to adulthood; others make it to adulthood but aren't very good at reproducing. Darwin reasoned that if those differences were due to certain heritable traits, those traits would be subject to natural selection. Natural selection is not the only force in evolution, but it is the most important one: it is the sculptor of beaks, and songs, and immune systems.

Just as comparative anatomy formed the basis of evolutionary thought in the nineteenth century, comparative genomics appears set to form the basis of evolutionary biology in the twenty-first. Darwin didn't know about genes, but ultimately, it is on genomes that natural selection leaves its fingerprints.

And a close look at those fingerprints shows natural selection acting in a new way. That matters, because until recently it's been an open question whether natural selection is as pervasive and powerful at shaping molecules as it is at shaping bodies.

At its most elemental level, natural selection acts on genes. And a gene is nothing more than an instruction to make a protein. Proteins are essential building blocks of the body (along with fats and sugars); they are large molecules that come in a wide range of shapes and sizes and have a variety of jobs. Some, such as hemoglobin, carry oxygen around in the blood. Others, such

as alcohol dehydrogenase, help digest alcohol. Still others form the scaffolding that helps cells stay in the right shape. If you're a finch, the protein calmodulin affects the shape of your beak. Cells make thousands of proteins—if you dry out a cell, the proteins will make up more than half the remaining mass.

But whether big or small, working in blood or beaks, each protein is just a chain of dozens or even hundreds of smaller molecules called amino acids. And each gene in DNA is an ordered list of the amino acids needed for making a particular protein.

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lection acts on protein function, that is, on how well proteins work. Mutations—changes in the DNA sequence of a gene—that improve how a protein does its job tend to spread: the owners of the mutations tend to produce more descendants. The bar-headed goose is a good example. This small, elegant goose from Central Asia has a white face and two dark bars, or stripes, on its head. But what makes the bird remarkable is that it has evolved a form of hemoglobin so sensitive to oxygen that it can breathe the thin air above the Himalayas.

Conversely, a mutation that disables a protein needed for survival may appear from time to time, but it cannot spread. If you've got a faulty collagen—the stuff of which cartilage and bones are made—you're likely to die as a baby, or even before you're born.

How well a protein does its job—its ability to carry oxygen or digest alcohol or act as scaffolding—depends to a great extent on its having a particular shape. Hemoglobin carries oxygen because the hemoglobin molecule has a little “pocket” that attracts and loosely holds oxygen molecules—a bit like one of those magnetic cups for paper clips. The shape of a protein depends on the way the string of amino acids folds up, which in turn depends on the properties of the amino acids in question. There are just twenty standard amino acids, and each is useful in particular ways, like the various shapes of Lego bricks. The amino acid glycine, for instance, is small and simple; it can serve as a hinge. Tryptophan is huge and bulky. Cysteine lends stability to a protein. And so on.

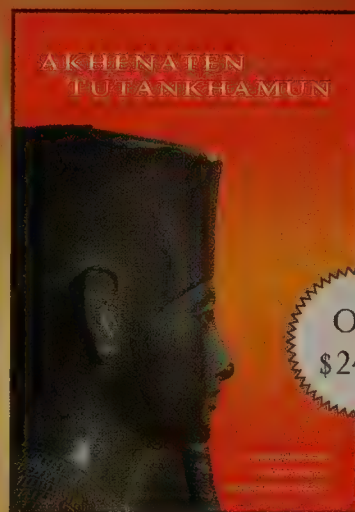
But often, only a few of the amino acids in a protein are essential to its function. At position 122, say, you must have glycine and no other—whereas the rest are interchangeable, at least to some extent. (Occasionally any of the twenty will work; more typically it'll be a choice between the two, or five, or ten that for the purposes of the protein have broadly similar properties.)

The question, then, is what determines which amino acids the cell

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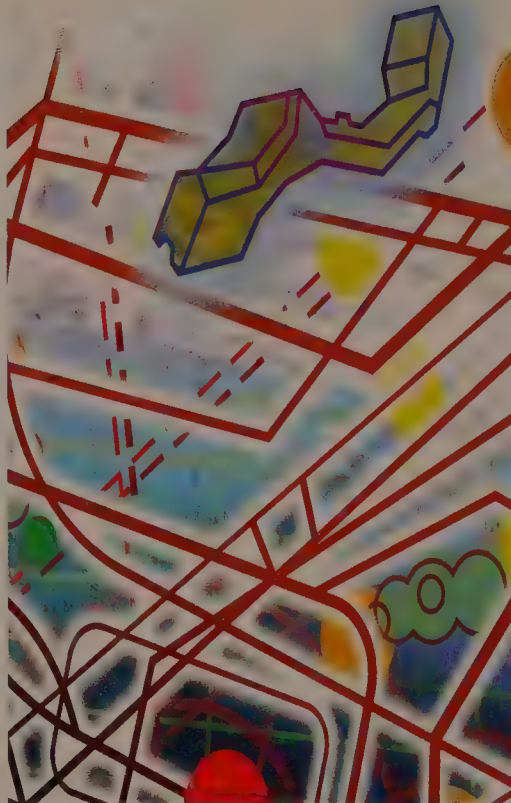
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evolves to use in the less critical parts of a protein? Until recently, the choice was put down to mutation—and assumed to be more or less random. Now investigators—among them Hiroshi Akashi of Pennsylvania State University in University Park, Jonathan Swire of Imperial College London, and Takashi Gojobori of the National Institute of Genetics in Mishima, Japan—have discovered it is not random, but to a large extent predictable. And it comes down to how much proteins cost to manufacture.

To see how cost comes into the picture, think of your cells as factories, churning out proteins much as an assembly line churns out cups for paper clips. The components—in this case, the amino acids—of the final product have to be built, or acquired. That takes energy. Furthermore, not all amino acids cost the same energy to make. Bulky, complicated tryptophan is particularly expensive; small and simple glycine is notably cheap.

If cells are sensitive to cost, you would expect them to evolve to use cheap amino acids wherever possible—particularly in the proteins they mass produce, compared with the ones they make only occasionally. The reason is straightforward: if you make protein *A* thousands of times more often than you make protein *B*, a mutation that enables you to make a cheaper version of protein *A* will have a far more pronounced effect than a similar mutation in protein *B*. The organism with the cheaper (but equally effective) version of *A* will get more substantial savings on its energy bills. If reducing cost is important—if the more miserly, cost-efficient creatures are more likely to survive and reproduce—then such a mutation is more likely to spread.

Sure enough, cost matters. You can look within the genomes of organisms that have one cell—such as brewer's yeast, or that common resident of the human gut, the bacterium *Escherichia coli*. Or you can look within the genomes of animals such as fruit flies, roundworms, and people, which have lots of different



cells. But either way, you find that selection to reduce cost has been pervasive. Given a choice among several amino acids, genomes reliably evolve to use the cheapest ones. In brewer's yeast, for instance, proteins that play a role in metabolism are made in large numbers, and are cheap, whereas transcription factors (proteins that control whether or not a particular gene gets turned on or not) are made in small quantities, and are generally expensive.

That "cost accounting" explains subtle but systematic differences in the ways various organisms build their proteins. For example, the energy it takes to make a given amino acid is different for creatures, like us, that live on the Earth's surface, than it is for denizens of the sulfurous vents in the deepest seas. There, the water is infernally hot, the pressure is immense, and life and its protein-building machinery are bathed in a volcanic brew. That changes the dynamics of chemical reactions. Some amino acids that are cheap for us surface-dwellers become expensive, and vice versa.

Those discoveries are exciting, for three reasons. First, selection to reduce cost operates differently from selection on how well a protein works. Without knowing a great deal about a particular protein, it's hard to predict whether a given mutation will affect

how well it does its job. But cost selection is something that applies to every position in a protein, and in a clear way. Each amino acid has a known price tag, so you can just go down the list of amino acids that a gene specifies, and work out which mutations would lead to cost savings, and by how much. It's a weaker force: a mutation that reduces cost can spread only if it doesn't mess up how well a protein does its job. After all, it's no good making proteins cheaply if they don't work. Cost selection is therefore most pronounced in the parts of the protein that are least critical to its function.

Second, cost selection opens up a new way to understand how evolution proceeds, molecule by molecule. It shows that natural selection is as powerful and pervasive in the sculpting of proteins as it is in the sculpting of beaks. But it also shows that comparing beaks and comparing genomes are not simply questions of scale. Processes that are invisible to the beakologist nonetheless exert profound effects on the very molecules from which the beak is made.

Finally, it's not every day that a new facet of natural selection is discovered. Since the publication of Darwin's *Origin of Species*, only three or four have come to light. There's sexual selection, which explains the evolution of extravagant traits, such as peacocks' tails, that increase mating success at the expense of surviving. There's kin selection, which explains such odd phenomena as the fact that worker bees cooperate in rearing offspring that are not their own. (They do so because they share many of the same genes.) There's selection on protein function. And now, there's selection on protein cost.

When it comes to making proteins, Mother Nature, it seems, is a terrible Scrooge.

OLIVIA JUDSON, a research fellow in the Division of Biology at Imperial College London, is the author of *Dr. Tatiana's Sex Advice to All Creation: The Definitive Guide to the Evolutionary Biology of Sex* (Owl Books, 2003).

AS HEARD ON PAUL HARVEY NEWS THE BEST AIR PURIFIER EVER Works 4 Ways to Attack Pollution from Air, Surfaces and Fabrics

Works to eliminate odors, dust, smoke, pollen, germs, mold, bacteria, viruses, pet dander, dust mites and much more

**Will eliminate the most noticeable indoor air pollutants in just 15 minutes
Provides relief from allergies and sinus**

By John Whitehead, Media Services

BioTech Research has announced EdenPURE™, the ultimate air purifier.

The EdenPURE™ is the best and most advanced air purifier on the market.

It runs super quiet and requires no filter replacement.

Unlike typical air purifiers which have only 1 or 2 mechanisms of eliminating pollution, the EdenPURE™ has 4 mechanisms which eliminate pollution.

There many different types of pollution and many of them, especially the worst, cannot be eliminated with the limited mechanisms of old-style air purifiers. The EdenPURE™ 4-mechanism system destroys all of the types of pollution.

The remarkable EdenPURE™ not only eliminates pollution from the air, but also eliminates pollution embedded in walls, ceilings, floors, carpets, furniture, clothing, and on countertops and other surfaces. It sanitizes everything in the house. The majority of air pollution comes from contaminated surfaces and fabrics.

The EdenPURE™ relieves allergies, asthma, respiratory problems, provides better sleep, more energy, and better health.

The air purification technology in the EdenPURE™ is that used by the federal government to purify air in the Space Shuttle and the International Space Station.

Old style HEPA filters mainly only remove dust and some allergens. They do not remove the most harmful pollutants such as bacteria, viruses, mold and yeast.

And if you have one of those air purifiers that has no fan, beware. More will be explained on this as you read on.

The EdenPURE™ has a super advanced fan that runs so quiet that you would have to put your ear up next to it to know that it's even running. And the EdenPURE™ is virtually maintenance free.

For more on the new EdenPURE™, here is my remarkable interview with John Whitaker, Chief of Research and Development for BioTech Research.

Q. BioTech Research has been in the air purification business for a long time and your previous air purifier model is an all-time best seller and was super effective. Why is the new EdenPURE™ air purifier so much better?

A. Yes, our previous model was an all-time best seller and in our opinion was the best air purifier on the market, which was also the opinion of

our customers.

But the EdenPURE™ is much more advanced. Our previous model used 2 very effective mechanisms to eliminate pollution, which were combinations of activated oxygen and ultraviolet light.

The EdenPURE™ utilizes 4 much more advanced electronic air purification mechanisms.

The advanced technology in the EdenPURE™ is that used in spacecrafts such as the Space Shuttle and the International Space Station.

Q. What about those air purifiers that have no fan?

A. It has been well documented in scientific tests that an air purifier without a fan cannot possibly remove pollution to any substantial level. Those types mainly remove pollution that is very close to the unit. That's fine if you're purifying the air in a broom closet, but not for a wide area. Also those units have you wiping off a plate to clean off the trapped pollution. But unless those units have ultraviolet light, that plate contains live bacteria and viruses that can be harmful.

Q. How does the EdenPURE™ eliminate pollution without requiring the air to go through the unit, and how does it eliminate pollution on surfaces and fabrics?

A. The EdenPURE™ has 4 electronic mechanisms of eliminating pollution that mimic the way it is done by nature's thunderstorm. Thunderstorms produce highly activated oxygen which destroys pollution and puts negative ions in the air that also destroy pollution and also promote better health. This super activated oxygen produced by thunderstorms is the most devastating to pollution and it is also the source of that aroma that you smell after a thunderstorm that people associate with super fresh air.

Three of the 4 electronic mechanisms in the EdenPURE™ go out and seek out pollution throughout the room, on surfaces, and in fabrics like guided missiles. The pollution cannot hide. These guided missiles also kill bacteria, viruses, yeast and mold.

The EdenPURE™ eliminates all pollution. Amongst the hundreds of pollutants EdenPURE™ eliminates besides bacteria, viruses, mold, yeast and allergens are: fungus, formaldehyde, fecal odors, perfumes, cologne, creosote from fireplaces, methylene chloride, phenols, PCB's, humic acid, DIMP's, glycerols, kepones,

EdenPURE™ - Never breathe bad air again



The EdenPURE™ Whole House Model



The EdenPURE™ Area Model

methyl ethyl ketones, acetone from fingernail filings, styrene, nitro compounds, formic acid, benzoic, butanes, ethanes, pentanes, propanes, methanes, alcohols, cyanides, detergents, phosphates and many more too numerous to mention.

Q. Does the EdenPURE™ require filter replacement like the old-style HEPA air purifiers?

A. No. There is a small 4 inch by 8 inch pre-filter that you simply clean periodically by running water over it. This pre-filter is made of highly durable mesh that will last a lifetime.

Q. So then the EdenPURE™ sanitizes everything in the house?

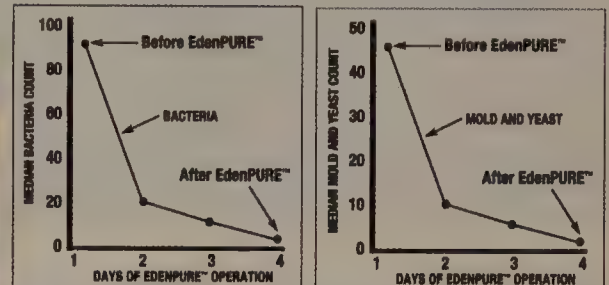
A. Yes. It sanitizes the air, walls, floors, ceiling, furniture, carpeting, countertop surfaces, sinks, bathtubs, toilets, and even sanitizes your clothes.

Q. How well does the EdenPURE™ work on eliminating odors?

A. The EdenPURE™ will eliminate all odors. It eliminates odors from cigarette smoke, urine, mildew, cooking odors, and any other odors in your home. The EdenPURE™ odor elimination is so powerful that it will eliminate the odor of a skunk in minutes.

After eliminating the odor from the air, the EdenPURE™ then goes to the source of the

Independent Test Results



EdenPURE™ eliminates most pollution in 15 minutes. Bacteria, mold and yeast are among the most difficult pollutants to eliminate. Old style air purifiers never eliminated them. The EdenPURE™ eliminated virtually all the bacteria, mold and yeast in only 24 hours. This independent laboratory test was conducted by Dr. Dee M. Graham, one of the leading air pollution experts in the world.

Testimonies of a few of the many EdenPURE™ satisfied customers

The EdenPURE™ is the most remarkable product that I have tried in years. All of the claims hold true. Not only did it eliminate the dust in my house, I have not had a sinus headache or scratchy throat since I began using it. The whole house smells fresh and clean. You would never be able to tell that I have two dogs and a cat. It is also nice not to have to bother changing filters. You just plug it in, turn it on and forget about it. It is truly refreshing to use a product that does everything that it is supposed to do and more.

Michelle Goldsmith

Before using the EdenPURE™ I had to take antihistamines and use allergy/sinus nasal spray. I was embarrassed because my eyes were red and I always sounded like I had a cold. I then got the EdenPURE™. I plugged in the EdenPURE™ and went about my daily duties when I suddenly noticed I wasn't coughing or wheezing or clearing my throat. This was incredible. The EdenPURE™ really works! I am so happy. My eyes are clear and I can breathe. I've tried many other air purifiers, they're all in my storage room with other failed products. The EdenPURE™ truly does what it claims to do.

Diane C. Vance

The EdenPURE™ Whole House Model purifies air in an area up to 3,000 sq. ft. The EdenPURE™ Area Model purifies air in an area up to 1,000 sq. ft.

End of interview.

For readers who want to obtain the EdenPURE™ at this 10 day sale price please see the Special Readers Discount Coupon on this page. Those readers ordering after 10 days from the date of this publication must pay regular price.

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The price of the EdenPURE™ Whole House Model, which purifies air up to 3,000 sq.ft. is \$372 plus \$22 shipping for a total of \$394 delivered. The price of the EdenPURE™ Area Model, which purifies air up to 1,000 sq. ft., is \$302 plus \$12 shipping for a total of \$314 delivered. People reading this publication get a \$75 discount, free shipping and handling and pay only \$297 for the Whole House Model delivered and only \$227 for the Area Model delivered if you order within 10 days. They come in the decorator color of grey which goes with any decor. There is a strict limit of 3 units at the discount price - no exceptions please.

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A Spring in Its Step

At top speed, an elephant does not run—by traditional standards—but it doesn't walk either.

By Adam Summers ~ Illustrations by Tom Moore

Do elephants run, or just walk briskly? According to many biomechanists—and the judges of Olympic racewalkers—an animal is running, not walking, when at some point in each stride all of its feet—two or four of them—are off the ground at once. Of course, for anyone who has faced charging elephants, the semantics of such things don't much matter: running or walking, a herd of elephants can cause heart palpitations. But the question is still worth asking, because when it comes to the way elephants move, the traditional distinction between running and walking isn't very informative. Besides going airborne, what else might mark the transition from amble to jog?

For openers, think about what happens when you take a leisurely walk. With each step, you plant a relatively straight leg on the ground.

Then your forward motion swings your hip and your center of gravity up and over the highest point of an arc centered on your foot. So a walking leg is like an upside-down pendulum, and your hip rises to its highest point in mid-stance.

Running is almost the reverse. When all your weight is on one foot, in mid-stance, your hip dips to its lowest point in the running cycle. That difference in hip position reflects a fundamental difference in the way energy is transferred and stored. Instead of transferring forward momentum into driving an inverted pendulum, your leg, in running, acts like a coiled spring. First it compresses, storing the energy of your body's falling mass as your foot lands on the ground.

Then your leg rebounds, releasing the stored energy and propelling your body upward and onward.

You might think that by now biologists would know full well how pachyderms prance. In fact, though, there are surprisingly few believable measures of their top speed, much less clear conceptions of the gait by which they max out. In fairness, studying the motion of fast-moving elephants poses difficulties and dangers. Zoo elephants make poor study subjects, simply because they have already been selected for being unlikely to zoom around their enclosures at high speed. And there aren't many places





Elephant legs, like primate legs, act like upside-down pendulums when their owners heave them forward in a slow walk (left). The hip (or shoulder) rises to its highest point when the foot below it is planted on the ground. As the foot pushes off, the hip or shoulder falls until the next foot is planted.

where elephants can be safely raced for a substantial distance in a straight line. John R. Hutchinson, a biomechanist at the Royal Veterinary College in London, and his collaborators faced those challenges with a video camera, experienced mahouts, and an international array of elephants—ranging from yearlings to sixty-year-old mommas—to determine whether elephants do more than walk.

Hutchinson and his colleagues painted white dots on the hips and shoulders of both Asian (*Elephas maximus*) and African (*Loxodonta africana*) elephants, and then videotaped

them under controlled conditions in Asia, Europe, and North America. The results debunked reports that some elephants could move at an astonishing twenty-five miles an hour. The top measured speed was about fifteen miles an hour—still quite brisk, but no faster than a reasonably fit person could run in terror.

What about running? Hutchinson clearly demonstrated that at no time does the entire elephant leave the ground. The animal does get three feet off the ground at once, but an Olympic judge for racewalking would still be happy with that gait. Hutchinson points out, however, that by other definitions, Jumbo is running.

Video analysis of the white dots of paint shows that in slow gaits the elephant's hip rises after the foot is planted, just as it does in a walking person. In the fast gait, however, the hip continues falling after footfall, and rebounds before the toe comes off the ground. That is consistent with the idea that the limbs are shifting from a pendulum-dominated walking gait to a springy run [see illustrations on these two pages]. Taken as units, the fast-moving forelimbs and hind limbs each have an aerial phase, so you could say that both ends of the elephant run, but not at the same time. (Work not yet published by Hutchinson indicates

that the shoulders don't undergo the same springlike compression as the hips, though.)

You might think that the elephant's peculiar way of "running" arose solely because of its huge size. But consider the white rhinoceros, the second-largest land animal, which can weigh more than 5,000 pounds. That's half as much as an adult African elephant. Yet the rhinoceros runs exactly like a horse—a really big, nearly blind, very grumpy horse. All four of its feet leave the ground, springing the behemoth forward from step to step.

Compare that with the gait of a baby elephant. A month-old baby, with a sprightly weight of 250 pounds, is fully able to charge along as fast as its full-grown parents—often a little faster. But it never goes airborne. The anatomy of elephant legs may simply not be suited to aerialism, or perhaps the running style is hardwired into the nervous system. But whatever the case, a growing elephant does not follow a progression of running styles from zebra-style to Cape buffalo to rhinoceros; it runs to type its whole life.

ADAM SUMMERS (asummers@uci.edu) is an associate professor of bioengineering and of ecology and evolutionary biology at the University of California, Irvine.



Faster-moving elephants change their hip movements. Instead of swinging like a pendulum, each leg acts more like a spring. In that gait, the hip dips to its lowest point when the foot is planted, then springs upward when the foot pushes off the ground. Although all four feet never leave the ground at the same time, both front and back "ends" of the elephant do.

Tracking the Elusive Jaguar

When you're following one of the biggest cats in the Western Hemisphere, be aware that one might also be following you.

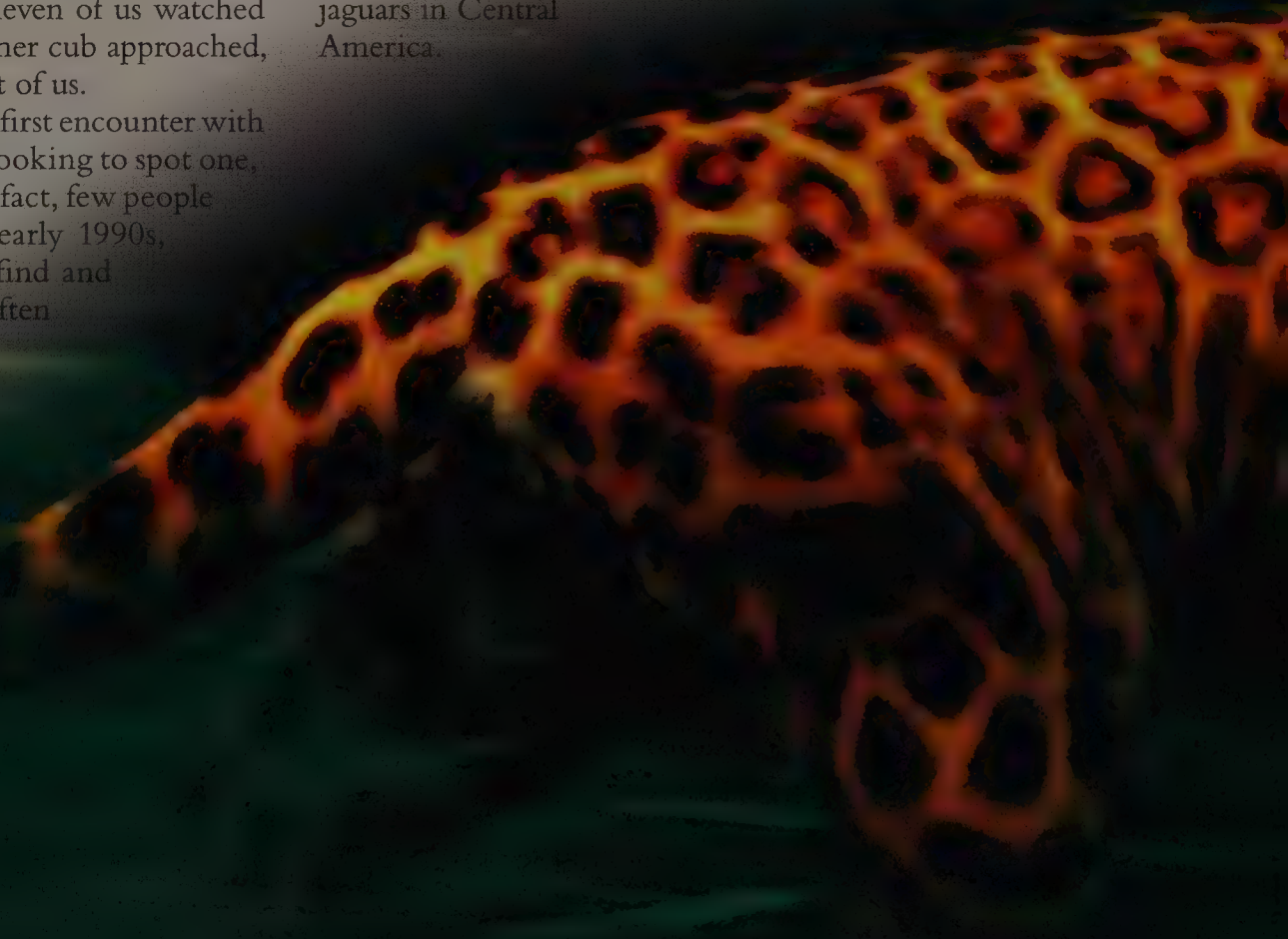
By Eduardo Carrillo

On a fresh May morning sixteen years ago, I was walking with ten of my students along a beach in Costa Rica's Corcovado National Park, when we came across the tracks of a sea turtle, leading out of the water and into the thick jungle beyond. A female turtle, we assumed, had come ashore to lay her eggs the night before. But no tracks led back to the water; instead, a set of jaguar paw prints crisscrossed the turtle's flippered swipes in the sand. Sure enough, we found the turtle in the woods, partly eaten. It was a seventy-five-pound olive ridley, which the jaguar had dragged about 300 feet into the forest. After taking a few pictures to document our find, we returned to the beach. Minutes later we spotted two animals about a mile away, loping in our direction. We promptly hid behind a fallen tree. All eleven of us watched in awe as a female jaguar and her cub approached, then passed within twenty feet of us.

That lucky sighting was my first encounter with a jaguar in the wild. I wasn't looking to spot one, let alone study the big cats. In fact, few people were studying them in the early 1990s, because they are so hard to find and follow. Jaguar field biologists often go several months without catching a glimpse of

one. Yet no radio collars, no traps, no rigged cameras had been necessary for my first sighting, which profoundly marked me, both as a professional biologist and as a human being. I wanted to know more about their ecology, to study the factors that have made them endangered, and to track them in their natural setting.

It would be three years before I saw my next wild jaguar. By then, my colleague Joel C. Saenz, now at the National University of Costa Rica in Heredia, and I had resorted to pooling our own scant savings to study the jaguar and its primary prey, the white-lipped peccary (*Tayassu pecari*) in Corcovado, which has one of the highest concentrations of jaguars in Central America.



Jaguars populate a snaking strip of land from southern Arizona and New Mexico southward to northern Argentina. Hunting pressures on both jaguars and their primary prey, plus deforestation, have caused the species, *Panthera onca*, to disappear from several areas within that stretch, including the whole of El Salvador and historically extensive ranges north of the Mexican border. In fact, sightings that mark the northern limit of the jaguar's range are recent; after decades of absence from the United States, the occasional jaguar was sighted in Arizona and New Mexico, beginning in 1996. In spite of its comeback, the jaguar is still considered in great danger of extinction. Needless to say, tracking the stealthy, solitary animals remains exceedingly difficult.

Our initial objective was to gather information about the peccaries' and jaguars' movement patterns. Was Corcovado large enough to maintain long-term populations of the two species? In spite of our limited resources, we determined that jaguars feed mainly on peccaries and marine turtles. The finding was surprising, because it is clear that a jaguar could eat any animal that crosses its path, including a human being. (There are no records, however, that jaguars have ever attacked people in the wild.) On reflection, though, opting for peccaries and sea turtles makes sense for the jaguars: adults of both

kinds of prey are easy targets and weigh between eighty and ninety pounds, so they provide a good deal of energy in one fell swoop [see photographs at bottom left of next page].

We also realized that jaguars are active hunters by day as much as by night. Although they are skillful tree climbers and excellent swimmers, they travel mainly on the ground, walking along man-made trails. According to our findings, male jaguars require at least ten square miles of territory to support their energy needs; females require about four square miles. The ranges of individuals, however, can overlap.

Those early observations of ours secured funding from the Wildlife Conservation Society (WCS), the National Geographic Society, and Idea Wild. Soon we were tracking more jaguars and more of their prey. On one memorable occasion Saenz and I had followed a group of peccaries across the jungle and shot a big one with a dart, hoping to collar it. But because the tranquilizer needs about ten minutes to take effect, we had to pursue the peccaries. Off we ran, jumping through the forest, across a dry, sandy streambed, through more forest, and across





Jaguar pelts, along with those of ocelots, are stacked high in a Brazilian poacher's store. In spite of international efforts to ban the sale of jaguar skins, the black market in them continues, and some of the cat's populations are still in decline.

another streambed—where we saw our footprints in the sand. We were going in circles! But on top of our footprints were a set of paw prints from a big jaguar that had also been following the peccaries—or perhaps following us. Somehow it seemed as if the jaguars of Corcovado remained one step ahead of us. Or is that behind?

Individual jaguars' coats vary in color on their backs from stunning golden-yellow to sandy brown, dotted with black, rounded rosettes. The jaguar's belly is white with solid black spots. The top coats of the jaguars enabled us to differentiate

them, and like many field investigators, we gave our subjects names. Monster was the largest cat we saw in Corcovado, weighing in at about 220 pounds. Rosa had a spot in the shape of a rose on the left side of her body, and she searched for sea turtles on the beach at every new Moon. Negra was the curious one, eager to investigate and rub against the camera "traps" that we began setting up near the beach in 2003.

The camera traps have become essential to our research in Corcovado and Guanacaste national parks [see map on opposite page]. We place automatic cameras at sites we think are attractive to the jaguars. Each site has infrared sensors that activate the cameras when a passing animal triggers them. What we want, of course, is to capture enough of the animal on film to identify it by its coat pattern, but what we often get is a picture of its tracks or a stray tail. In any event, one of our most effective tricks for attracting jaguars to our camera stations turns out to be . . . men's cologne.

The idea came from a chat I had some years ago with a WCS colleague. Men's perfume had been useful, he told me, in attracting wild cats to scent stations elsewhere. With a little experimentation in Corcovado, we found out that jaguars cannot resist the smell of Calvin Klein cologne, specifically "Obsession." They seek out the fragrance from miles away—perhaps because of the civet scent in it. Regardless, the stuff works, and so all our stations are baited with the perfume. The photographs enable us to identify individuals by their unique pattern of spots, as well as to make general estimates of the kinds and numbers of prey that pass by the area.



Three favorite prey of the jaguar are pictured above. The white-lipped peccary (left) and sea turtle hatchlings (middle, with a jaguar print), as well as adult sea turtles, are the most hunted prey in Corcovado National Park. The squirrel monkey (right) often evades its feline nemesis, thanks in part to the vocal warnings of its fellow monkeys.

If you're lucky enough to see a wild jaguar in person, the observation is far more thrilling, and can be more informative, than a photograph. Once I went out to look for Jill (a female jaguar named in honor of my first field assistant), not long after putting a radio collar on her. I wanted to make sure her radio transmitter was working properly, and to check on her general well-being.

After about an hour of walking through the jungle with my radio antennas, I located Jill resting among the buttresses of a tree. She was only eighty feet or so from where I stood. On impulse, I decided to throw myself on the ground and try to slither toward her on the forest floor. I was making good progress on my stomach when a group of squirrel monkeys started calling from the trees above me. I recognized the particular call they were making—something like that of a barking dog—as their danger signal.

I looked up at them, but they weren't looking at me. I thought, "Hmmm, they usually make that sound when they see either a snake . . . or a feline." With that thought, I turned to my right and froze on the spot: just fifteen feet away was a male jaguar. Again a jaguar had been following my movements without my knowledge. Once this jaguar knew I had noticed him, he simply turned and walked casually into the thick woods. I was left puzzling over his behavior, but not fearful. Especially after that incident, fear was not a factor for me; the animals simply are not aggressive toward people.

In many ways, jaguars benefit from being non-confrontational. A stealthy, solitary animal can save itself the trauma of wounds from hunting prey, competing for potential mates, or fighting territorial battles. A wound in the jungle, after all, can mean a hasty death, since parasites abound.

Only in two-week-long mating encounters, and in the rearing of the young—a process that takes about eighteen months—do jaguars interact with one another. Most mothers bear two cubs, though litters of one cub or as many as four are not uncommon. In some cases a litter can include one spotted and one black cub; people once distinguished the black jaguars as "panthers." (The term is a general one, however, and it has also been applied to leopards and cougars with entirely black coats.)

Evolution has placed jaguars at the top of the food chain, but left them with one possible weakness: poor sprinting skills. Unlike the other big cats in the genus *Panthera*—including leopards, lions, and tigers—jaguars don't run much in pursuit of their prey. Instead, they track, and then pounce. Making incredibly silent approaches, the cats simply lunge from the shadows of the jungle and swiftly



Many national parks of Costa Rica (dark green) offer some protection for the country's threatened jaguars. The author has conducted extensive field studies in Corcovado National Park, in the southwest corner of the country.

bite their prey in the neck. Why run when there's nothing worth running from and nobody knows you're coming?

In spite of their lack of aggression, jaguars are coming in closer contact with people as we encroach on their habitats. In Costa Rica, farmers have recently shot jaguars when the cats strayed from within national parks and raided pig farms or cattle ranches. Yet the jaguars have good reason for fanning out to seek alternative food sources. Three of their favorite prey species, the white-lipped peccary, the collared peccary, and the paca (a large rodent related to the common agouti), are all falling victim to massive hunting for their succulent meat.

Peccary or paca poaching often takes place on the edges of protected areas, or even inside the park boundaries if rangers aren't vigilant, since that's where more animals reside. In Corcovado, for instance, the peccary population has fallen by some 60 percent since 2000 because of hunting pressure. The hunters use high-caliber automatic rifles, such as AK-47s, which can kill as many as fifty animals in a few minutes. During the same six years, jaguar numbers in Corcovado dropped from about 150 animals to a mere thirty or forty.

When jaguars lose their food supply and face starvation, they naturally seek other means of survival. Farms become targets. And once they kill a domestic cow or pig, they learn that farm animals are easy prey. So hungry jaguars, in turn, become the targets of farmers' wrath. Fortunately, funding



Adult jaguars are excellent tree climbers, often using trees as resting spots, scratching posts, or caches for their prey. The author once found a marine turtle stashed ten feet above the ground in Costa Rica's Guanacaste National Park.

in 2005 from the Moore Foundation supported the hiring of fifty-three new park rangers for conservation areas on the Osa Peninsula. Our studies show that the peccary population has recuperated since then. But it will take some years before the jaguar population begins to make a noticeable recovery in Corcovado.

Efforts to stop deforestation in some areas and to support ecological restoration in parks such as Guanacaste are also helping support the jaguar populations. Still, three Costa Rican national parks, Tortuguero, La Amistad, and Braulio Carrillo, are suffering serious losses of their jaguars.

Another threat to the cats' safety comes from the fur trade, which underwent frenzied growth in the 1960s. In Brazil alone, 15,000 jaguars were being

killed every year. The year 1973 marked a change in the trade of jaguar pelts: the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) helped to cut down on the traffic in jaguar pelts. Yet in countries such as Nicaragua, a black market for pelts still exists [see photograph at top of page 32]. There you can buy a full pelt for about \$200, not to mention other products such as belts, shoes, and wallets.

Costa Rica depends ever more heavily on tourism and wildlife conservation for its income. People are beginning to understand the importance of protecting the country's living resources. Nevertheless, a single country cannot make much headway without the support of its neighbors. Alan Rabinowitz, a WCS biologist who has worked avidly to protect jaguars in Belize, has proposed establishing a multinational "Jaguar Corridor," which would run from the southwestern U.S. through to northern Argentina. Ideally, the corridor would include enough protected areas in every country along the way to sustain a healthy, contiguous jaguar population. Barriers, both physical and political, continue to prevent that kind of linkage. One case in point is the proposed "border fence" between the U.S. and Mexico.

Whether or not a Jaguar Corridor is established, new research must focus on mapping and understanding the distribution of jaguars across the countries that make up that corridor. In Costa Rica, my colleagues and I are making progress in determining how the parks' managers can best protect jaguars and their prey. We must continue that work—much about the jaguars has yet to be discovered—but, more urgently, we need to extend our existing collaborations to other research teams. The goal must be to ensure that populations of jaguars do not continue to disappear from any of our countries. Education and bans on hunting the jaguars' prey inside protected areas will help.

Human beings have to remember that we, too, belong to nature. What we do to nature, we do to ourselves. The linkages of cause and effect are circular, just as my chase of the peccaries was. Like the jaguar in the forest, what is lurking in our shaded future may be unrecognized and unknown, but it may also be ready to cover our heavy tracks with new and unexpected ones of an entirely different cast. □

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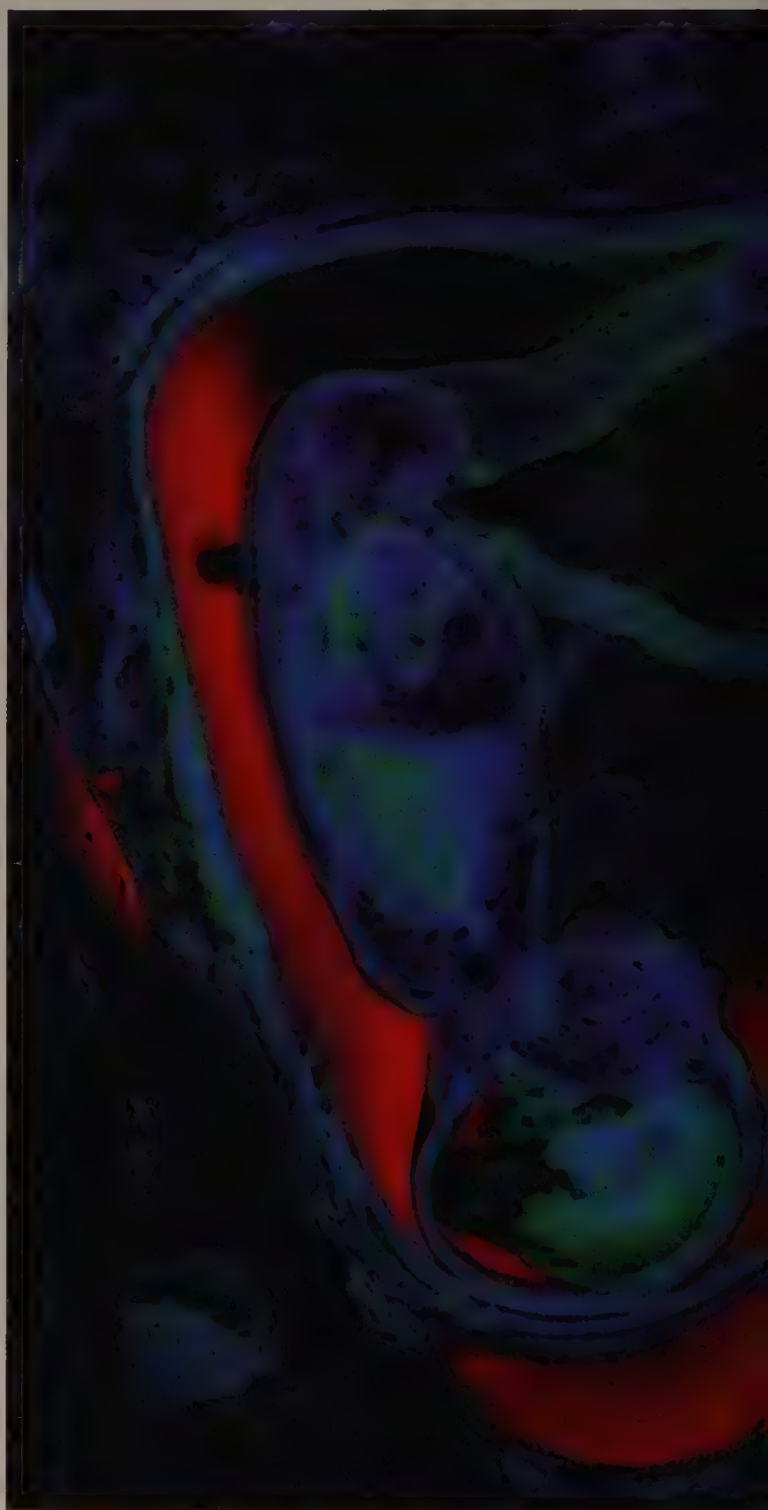
What keeps a mother's immune system from treating her baby as foreign tissue? A new theory resolves the paradox.

By Gil Mor

Why didn't your mother reject you? I don't mean psychologically, but immunologically. That may still sound like a strange question, but think about what happens when a mother conceives a child. Each baby has a mother and a father, and as a result carries a mix of genetic material from both parents. The father's genetic material is foreign to the mother. Normally when the immune system encounters something within the body that is foreign ("nonself"), it attacks and eliminates the outsider. So why doesn't the mother's immune system reject the developing embryo as a foreign body, just as it would reject a thorn, a virus, or a tissue graft from another person?

More than fifty years ago the Nobel prize-winning English transplant-immunologist Peter B. Medawar posed what has become known as the "immunological paradox of pregnancy." The fetus, Medawar argued, is like a semiforeign transplant, because half of its genes come from the father. Therefore, he concluded, the mother's immune system and the fetus must be locked in conflict. Subsequent studies showed that the immune system is indeed active at the site where the developing embryo attaches to the uterus, or "implants," at the beginning of pregnancy. Thus an aggressive maternal immune system, it seemed, would take to the ramparts against the embryo, which further implied that the embryo in turn would need to take evasive or defensive measures. Medawar's way of posing the problem still dominates current thinking about the immunology of pregnancy, though exactly how the fetal cells evade maternal surveillance is a matter of debate.

In 2004 I was in Japan to deliver a talk on the immunology of pregnancy. In preparing for the talk, I began reviewing data showing that removing natural killer cells, a kind of immune-system cell, from certain strains of pregnant mice causes the mice to miscarry. Those findings were the exact



opposite of what you would expect, particularly from Medawar's point of view: If the immune system is a threat to the embryo, you would think that getting rid of the immune-system cells that kill an invader would help the pregnancy succeed.

That's when I had a classic "aha" moment. I realized that those results were similar to the ones that I and my colleagues had obtained a couple of years before with macrophages, another kind of immune-system cell. We had discovered that removing macrophages also harmed the pregnancy. At that time we could not explain those results, but they had been "sleeping" in the back of my mind ever since.

In the three years since my "aha" moment, I have developed a new perspective on the way the mother's immune system and the fetus interact. Although there clearly is a mechanism that prevents the mother's immune system from treating the fetus as a foreign body, I think conventional wisdom has the role of the mother's immune system completely backwards. Rather than threatening the fetus, her immune system plays a critical role in the success of pregnancy, particularly in its early stages.

To appreciate how the early fetal cells can cooperate with the immune system of the mother, recall what happens after a sperm fertilizes an egg. The fertilized egg rapidly divides to form the blastocyst, a hollow ball of cells with an inner cell mass and outer layer. The inner cell mass gives rise to the embryo, which develops

into a fetus about eight weeks after conception, when the major organs of the future baby become recognizable. The outer layer of the blastocyst becomes the so-called trophoblast. The trophoblast cells invade the lining of the uterus and thereby begin implantation.

Within a few weeks of making its home in the uterus, the trophoblast further transforms into the fetal part of the placenta, the conduit for the passage of nutrients and oxygen from mother to fetus. (Some of the mother's cells form a second part of the mature placenta.)

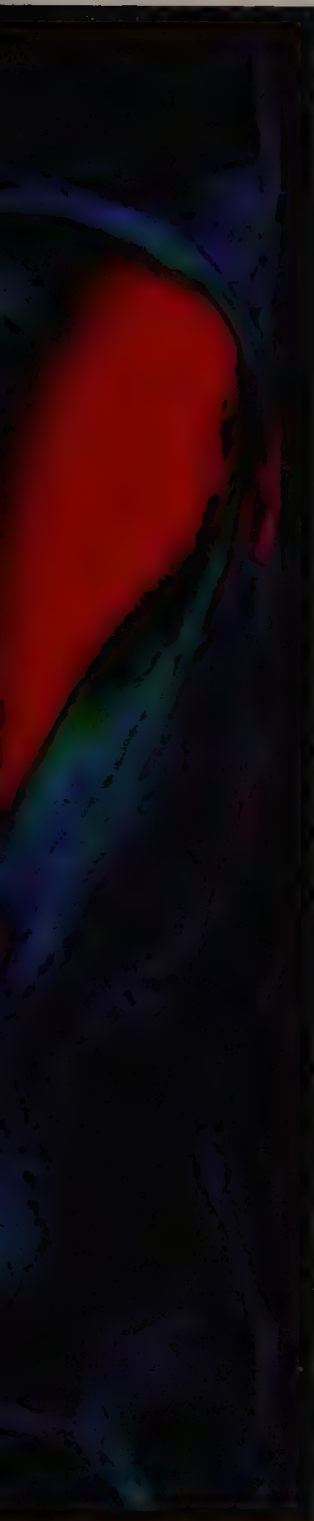
The immune system eliminates invaders in two ways. The first, known as the innate immune response, neutralizes invading pathogens before they can harm the body. In a wound, for example, white blood cells known as macrophages engulf invading microorganisms and also release signaling proteins called cytokines. The signals activate other parts of the immune system, such as natural killer cells, which gobble up everything foreign in their path. This response requires no prior exposure to the invader.

Acquired immunity is an additional, highly specific, and generally more sophisticated response. It relies on antibodies and specialized white blood cells called *B* cells and *T* cells that target particular foreign material to which the body has already been exposed. Those immune-system cells become active and multiply if they encounter molecules or parts of molecules called antigens associated with foreign organisms. The immune-system cells "remember" their encounter with those specific antigens and react to further exposures faster and more vigorously.

In 1991 Gail T. Colbern of the Medical Research Institute in San Francisco and Elliott K. Main, now at the California Pacific Medical Center in San Francisco, redefined the conceptual framework of reproductive immunology. The trophoblast cells, they realized, are the only part of the differentiating blastocyst that interacts directly with the mother's immune system. The embryo itself—and the fetus to which the embryo gives rise—has no direct contact with maternal immune cells. As a result, Colbern and Main argued, the real puzzle is not why the mother's immune system tolerates the fetus, but why it tolerates the trophoblast cells.

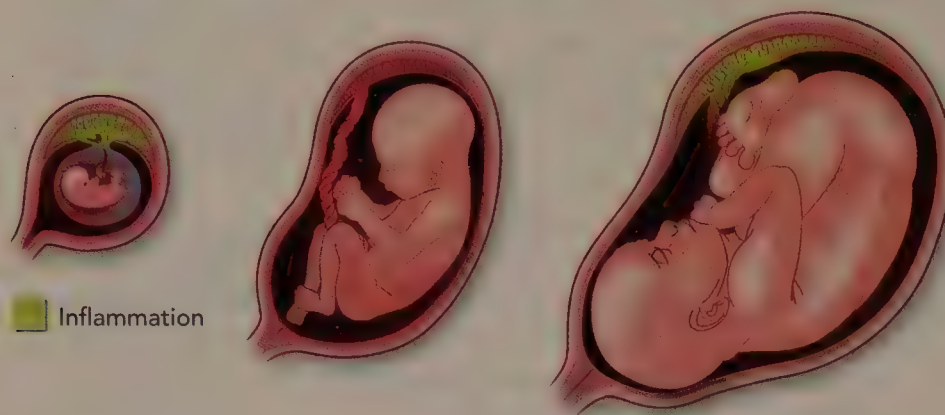
Several hypotheses have been put forward to explain the mother's tolerance, including:

- first, that the trophoblast forms some kind of mechanical barrier;
- second, that the mother's immune system is suppressed during pregnancy;



Colored MRI image shows a human fetus near term, its head downward against the birth canal of its mother and its umbilical cord running roughly left-to-right just above the center of the image. A fetus carries a mix of genetic material from both parents in its genome. According to the general rules of immunology, the mother's immune system should reject her fetus as foreign ("non-self") the way it would a tissue graft from another person, raising what is known as the "immunological paradox of pregnancy."

CHRONOLOGY:
MATERNAL IMMUNITY AND THE DEVELOPING PREGNANCY



	8-12 WEEKS	3-6 MONTHS	7-9 MONTHS
IMMUNE REACTION	Open-wound stage: embryo elicits mother's immune response (inflammation)	No inflammation: mother and fetus reach symbiosis	Another inflammation leads to labor
SYMPTOMS	Nausea, fever; contributes to "morning sickness"	None (mother feels good)	Fatigue, muscle contractions, possible fever
POSSIBLE COMPLICATIONS	Miscarriage (due to infection); No implantation (due to lack of inflammation)	Preterm labor (due to viral infection)	Preeclampsia, prolonged pregnancy, intrauterine fetal death

- third, that the mother's immune system is suppressed, but only locally, in the vicinity of the trophoblast; and
- fourth, that the balance of cytokines, the proteins that regulate the mother's immune response, shifts during pregnancy.

Although some of those hypotheses are more widely accepted than others, each still attracts its fair share of proponents. After my "aha" moment in Japan three years ago, I started thinking more critically about each of them, and noticing their flaws.

According to the first hypothesis, a mechanical barrier prevents cells from moving in either direction between mother and fetus. Thus the barrier creates a state of "immunologic ignorance": antigens inside the barrier are never detected by the immune system without. I don't find that explanation convincing, because studies indicate the placenta is not as impermeable as originally envisioned.

In 1996, for instance, investigators at Harvard and Tufts universities, and at the New England Medical Center in Boston, detected fetal cells in mothers' bodies decades after pregnancy. Furthermore, the fetal cells could infiltrate maternal tissues and differentiate into liver, blood, skin, and other cell types. Originally, it was thought that such fetal cells in the mothers caused many of the autoimmune diseases that afflict women.

But in 2002, Tufts investigators demonstrated that the fetal cells may play a critical role in repairing a mother's damaged tissue. In one case, a woman suffering from hepatitis, a serious liver disease, stopped her treatment against medical advice. Surprisingly, she recovered. Her own body could not regenerate healthy liver cells, so the investigators were baffled. When they tested a specimen of her liver, though, they discovered it incorporated thousands of male cells still left in her circulation from a pregnancy nearly two decades before her illness. Those left-over fetal cells had generated new liver cells, and thereby saved the mother's life. What a nice way for a child to repay its mother's dedication! So much for the impermeable-barrier theory.

For proponents of the second hypothesis, pregnancy involves a state of systemic immune suppression. But I find that hard to believe, too, particularly from an evolutionary point of view. When our ancestors were walking through the forest, they did not always wash their hands or clean their food before serving dinner. And they were continuously exposed to bacteria, parasites, and other microorganisms. If pregnant women were immunologically suppressed, they would have died within hours of exposure to those pathogens, and the human species would have been wiped out. Even today in many parts of the world pregnant women are constantly exposed to harsh, unsanitary conditions. A suppressed immune system would make it impossible for a mother and her fetus to survive.

In particular, if the mother's immune system were suppressed during pregnancy, every pregnant woman infected with HIV would die of AIDS, and that is not the case. In places where the disease is pandemic, such as Africa, women do not die of AIDS during pregnancy; in fact, the opposite is the case—HIV is *less* likely to develop into full-blown AIDS during pregnancy. The immune forces that the trophoblast has called to its aid keep the virus at bay.

According to the third hypothesis, local immune suppression, the mother's immune-system cells that would ordinarily attack the "foreign" cells of the trophoblast are prevented from doing so. One proposed mechanism is that the attacking

cells are simply removed by the mother's *T* regulatory cells. A second proposed mechanism is that a protein secreted by the trophoblast cells, known as Fas ligand protein (FasL), binds to another protein on the mother's would-be attacker cells called Fas. The binding induces programmed cell death of the would-be attacker cell.

But the results of my studies have been the opposite of what one would expect if either of those mechanisms accounted for the mother's tolerance of the trophoblast. First, recall that in the studies that inspired my "aha" moment, *removing* immune-system cells (macrophages) that would be expected to attack the trophoblast caused pregnant mice to miscarry. Furthermore, subsequent studies, which we and others have confirmed, have shown that mice lacking either Fas or FasL protein can reproduce with no apparent complications of pregnancy.

The fourth hypothesis maintains that the balance of cytokines in the mother's body shifts during pregnancy, thereby changing the details of her immune response.

When a woman is not pregnant, her immune system responds to infection with an arm of the immune system dominated by cytolytic *T* cells. These cells are mobilized to destroy the cells that have become infected. According to the cytokine-shift hypothesis, however, pregnancy changes the balance, suppressing the inflammatory response and creating, instead, an anti-inflammatory environment.

The cytokine-shift hypothesis, also known as the anti-inflammatory theory of pregnancy, was embraced enthusiastically when it was first proposed in 1993. Numerous studies measured cytokine levels in the mother's blood, in an effort to prove that pregnancy is an anti-inflammatory condition. Investigators also looked for evidence that a shift toward higher concentrations of pro-inflammatory cytokines would lead to miscarriage or to other complications of pregnancy. Some studies did indeed find a shift toward anti-inflammatory cytokines in the mother's blood, but other studies did not.

My own theory grows out of an attempt to understand those contradictory results. In my view, the contradiction is only apparent, and can be traced to an oversimplification. In the studies of inflammation, the entire pregnancy was evaluated as a single event. In reality, though, pregnancy has several chapters, each one marked by the way the mother feels. I believe that, depending on the stage, pregnancy is a pro- or anti-inflammatory condition.

In the first trimester, the mother's body treats implantation as if it were an open wound that requires a strong inflammatory response. After all, to implant itself in the wall of the uterus, the embryo has to break through the uterine lining, damage the underlying tissue, and disrupt the mother's blood vessels to secure an adequate blood supply. All those activities require an inflammatory response from the mother to secure the adequate repair of the uterus and the removal of dying cells. During this period the mother feels terrible because her entire body is struggling to adapt to the presence of the fetus. Yet without her immune reaction, the pregnancy will not "take."

The second trimester of pregnancy is, in many ways, the best time for the mother. The period is one of growth and development. Both mother and fetus reach a symbiotic stage that is anti-inflammatory: now that the "wound" is healed, the inflammation has died down. The woman no longer suffers from nausea and fever as she did in the first trimester.

In the third trimester the fetus completes its devel-

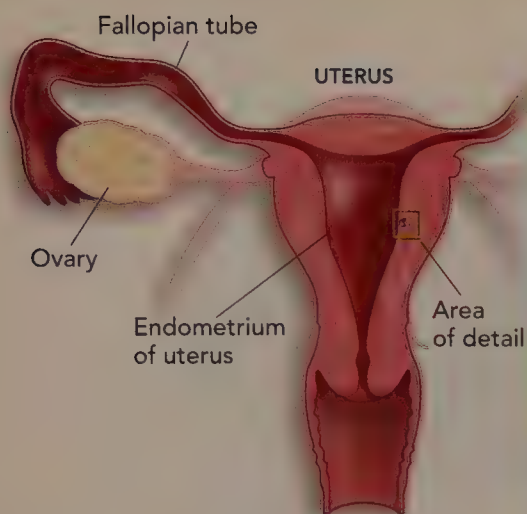
opment. All its organs become functional and ready to deal with the external world. Now the mother needs to deliver the baby. And

delivery, too, is achieved through inflammation: an influx of the mother's immune-system cells into the uterus provokes the release of hormones that induce labor, or contractions of the uterus. The contractions expel, or deliver, the baby.

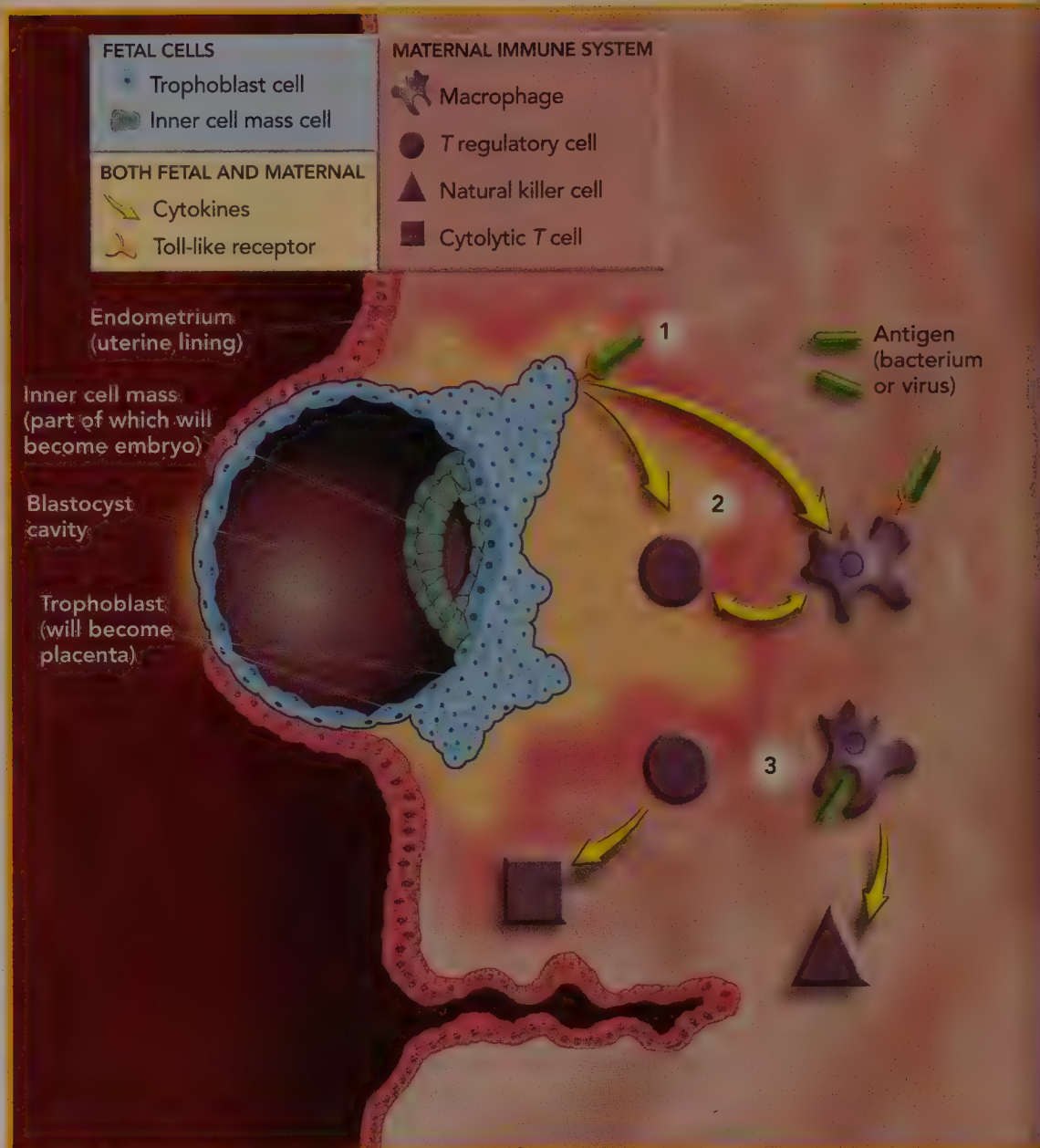
In analyzing the flaws in the four earlier hypotheses, I realized that reproductive immunology has always followed mainstream immunology. Beginning with Peter Medawar, immunologists have viewed the placenta—or its precursor, the trophoblast—as a "piece of skin" marked with the father's proteins. But the assumption shared by all four hypotheses—that the mother must somehow be tolerating a half-foreign graft—has never been convincingly proved. Instead, by proceeding from an unproved assumption, the hypotheses have deepened the confusion about the role of the immune system during pregnancy.

The placenta is more than just a transplanted piece of skin. From an evolutionary perspective, that is hardly surprising. Pregnancy and implantation, after all, have been taking place ever since the development of the mammalian uterus more than 180 million years ago [see "*The Birth of the Uterus*," by Vincent J. Lynch and Günter P. Wagner, December 2005/January 2006]. The real surprise would be

Understanding how the embryo and its mother's immune system interact could help treat complications of pregnancy.



Blastocyst (rapidly dividing fertilized egg) implants in the lining of the uterus (schematic diagram above), provoking an inflammation response from the mother. According to the author's theory, outlined in the enlarged area of the schematic diagram (right), the trophoblast (blue) coordinates the local actions of the mother's immune-system cells (purple), via signaling proteins called cytokines. Three steps of that coordinated immune response to a foreign body (antigen) are shown: (1) Toll-like receptors on trophoblast cells and on the macrophages of the mother sense the antigen. (2) The activated trophoblast cells signal the mother's macrophages and her T regulatory cells via cytokines about the nature of the threat; the macrophages and the T regulatory cells also coordinate their activities via cytokine signals. (3) The macrophages destroy the invader and signal the mother's natural killer cells to suppress their activity, while the activated T regulatory cells suppress the cytolytic T cells. The two suppressive actions prevent an attack by the mother's immune system on the trophoblast.



to find that the mother's immune system had *not* learned to recognize her own offspring.

My research suggests that the trophoblast and the mother's immune system join forces to fight their common enemies: infectious microorganisms. When the trophoblast cells "call for help," the mother's immune system responds with coordinated actions. In short, the mother's immune system becomes active in the early stages of her pregnancy to protect, not to harm, the embryo, to promote implantation and subsequent embryonic growth.

To picture how such a complex physiological partnership can function, think of the cells of the mother's immune system as musicians in an orchestra. The macrophages are one section, the T cells another, the natural killer cells a third. During pregnancy, our studies suggest, the trophoblast functions as a guest conductor. The success of the pregnancy—the musical performance—depends on how well the trophoblast communicates with each kind of cell in the immune

system, and on how well they all work together. I am trying to understand how that orchestra works at the molecular level: how the trophoblast recognizes what is nearby, and, on the basis of that information, what kinds of signals it sends that coordinate cellular activities at the implantation site.

Our recent studies demonstrate that the cells of the trophoblast share a feature with macrophages and other kinds of cells that make up the innate immune system. They all have signal receivers known as Toll-like receptors (TLRs) displayed on their cell membranes. TLRs enable trophoblast cells to sense bacteria, viruses, dead maternal cells (killed during implantation), and damaged tissue in the trophoblast environment. Before our studies, only immune cells were thought to have TLRs.

When the trophoblast, through its TLRs, senses one of those targets, it secretes a specific set of cytokines that act on each kind of immune cell present at the implantation site [see illustration above].

The cytokine signals “educate” the immune cells, conferring specific properties on them that enable them to help with implantation. For example, in response to the signals, natural killer cells help transform the mother’s blood vessels, macrophages help the blastocyst migrate to the uterine wall, and dendritic cells help in attaching the blastocyst.

A particularly important part of cytokine-mediated “education” is getting macrophages to clean up dead maternal cells. When the trophoblast invades the uterus, it sends out signals that program the death of some uterine cells, to make room for the blastocyst. The dead uterine cells need to be removed quickly or disease will result in the mother. The trophoblast cells signal the macrophages to come and clean up the dead-cell mess.

At the same time, cytokines from trophoblast cells signal *T* regulatory cells to suppress the normal actions of natural killer cells and cytolytic *T* cells. By suppressing those cells, the trophoblast avoids being attacked by the mother’s immune system. Macrophages “educated” by the trophoblast, on encountering an antigen, signal the *T* regulatory cells to suppress the natural killer cells for the same reason.

All that exquisitely synchronized activity can be derailed by viral or bacterial infection. Clinical studies have shown that infections cause as much as 40 percent of incidence of preterm labor. Furthermore, of the most severe cases of preterm delivery (pregnancies that end after less than thirty weeks of gestation), 80 percent show evidence of infection.

That raises another conundrum about immunity and pregnancy. Inflammation from infection often complicates a pregnancy, jeopardizing the well-being of the mother and her developing embryo. Nature’s solution is harsh: to save the mother, the infection not only causes inflammation, but also triggers early delivery, or miscarriage. The conundrum is that inflammation is also necessary for normal implantation. How can such diametrically opposing outcomes both originate from an inflammatory response?

To our surprise, my research group discovered that the signals triggering miscarriage may be initiated by the same guest conductor, the trophoblast. If a virus, say, is infecting the uterus, the trophoblast recognizes the virus through its TLRs, just as in normal implantation the trophoblast recognizes dead cells from the mother’s uterus. With the virus, however, the trophoblast’s response is different. Its cells signal the mother’s immune-system cells to mount an aggressive immune response. Instead of suppressing her cytolytic *T* cells and natural killer cells, she activates them. Not only do they attack the infection, but they attack the trophoblast as well.

The battered embryonic tissue is then expelled; the mother miscarries.

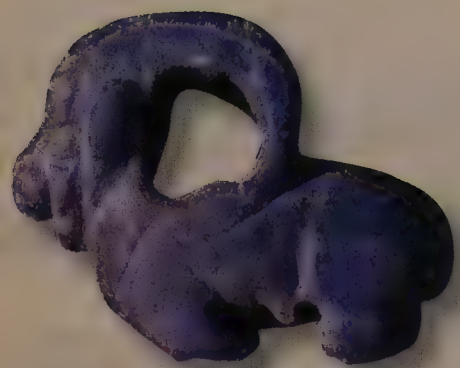
Even though too many bacteria in the upper reproductive tract can lead to miscarriage, some bacteria may be needed to stimulate the mother’s initial inflammatory response. The upper reproductive tract, which includes the inside of the uterus, was once thought to be a sterile environment. It is now known, however, to be continuously exposed to microorganisms. They can reach the uterus either as hitchhikers carried along by sperm or via the peristaltic waves of orgasm. We are currently exploring the possibility that bacteria play an essential role in priming the uterus for implantation.

How could they do so? During the critical time the embryo can implant, adhesion molecules on the uterine lining change their adhesive strength so that the blastocyst can become attached. Those changes of adhesiveness are thought to be induced by semen. It is possible that bacteria help spread the semen across the uterine lining, providing the pro-inflammatory stimuli needed for the blastocyst to attach. Bacteria may therefore be essential for implantation, and thus for pregnancy itself.

Our studies provide an alternative perspective on the role of the mother’s innate immune system in pregnancy. I would hope that some day my model will lead to early diagnosis and more effective treatment of obstetrical conditions in which the immune system plays a central role. In particular, understanding how the maternal immune system interacts with the trophoblast will enable medical investigators to develop new tests to monitor alterations in the normal cytokine balance that could lead to pregnancy complications. New therapies might also be developed to treat such complications of pregnancy as preeclampsia and recurrent, multiple miscarriages.

Preeclampsia accounts for 40 percent of maternal deaths in many countries of the developing world. It is known to be caused by inflammatory conditions that damage the mother’s blood vessels. Unexplained multiple miscarriages probably also result from immune-system disorders. Both those killers, and others, are likely to continue causing heartbreak and devastation until biologists can disentangle the intricate strands of the immunology of pregnancy. □

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Hidden Tombs of Ancient Syria

Evidence of animal and possibly human sacrifice suggests that burials at Tell Umm el-Marra were those of Bronze Age royalty.

By Glenn M. Schwartz

Although nearly seven years have passed, I still vividly remember the events of June 10, 2000. Our archaeological team of students and specialists, about fifteen strong, had begun the third week of a two-month excavation season on the Jabbul Plain of northern Syria. We were bracing ourselves for the hot and dry summer days we could expect at our site, Tell Umm el-Marra. A *tell* (the word means “mound” in Arabic) is not a natural feature. Rather, it is an archaeological time capsule, with layers of mud bricks, stones, artifacts, and other materials that have accumulated for thousands of years as buildings were lived in, abandoned, fell into ruin, and finally served as the foundations for a new generation of buildings. At Tell Umm el-Marra the remains have accumulated to a height of twenty-seven feet across an area of fifty acres. The mound is one of scores that dot the otherwise featureless plain.

In earlier field seasons, our team had whittled away happily at parts of the mound, exploring the residue of a small city founded about 2800 B.C. But on this particular morning I was feeling disappointed. We had begun digging trenches in what we referred to as the “acropolis,” a three-and-a-half-acre area at the center of the site. A six-foot-thick wall of mud bricks built around the acropolis in about 1800 B.C. was a tantalizing sign: if ancient inhabitants had taken the trouble to build such a wall, we reasoned, it must have enclosed an important building—a palace, perhaps, or a temple. But when we had dug down to the habitation layer dating from the time

of the wall, all we found was a shapeless heap of stone cobbles and boulders.

Disappointed? Yes, but certainly not ready to quit. Could the stones and cobbles still be concealing the foundations of a palace or temple? I



Excavation of the upper layer of Tomb 1, right, at Tell Umm el-Marra, in Syria, revealed bones of two young women and two infants, along with pottery and various ornaments. Dating from ca. 2300 b.c., the tomb was the first of several discovered within the ruins of a small Bronze Age city. Top left: Amulet in the form of a wild goat, carved in lapis lazuli, was found near the neck of one of the women; it is pictured at two times actual size. An aerial view of the site and its surroundings forms the background of these two pages.

asked Alice Petty, a graduate student on our team, to remove the rocks in her trench—after carefully documenting them, of course—and dig deeper. As she did, she uncovered the tops of stone walls that enclosed a rectangular room about twelve feet long by eight feet wide. By the style of the pottery shards in the fill, I judged the room to date from an earlier period. Actually, though, it still didn't look very promising; I rather tepidly suggested to Petty that she keep digging and let me know if anything interesting turned up.

But as she proceeded with the work, my skepticism turned to excitement. Petty started finding unbroken vessels of pottery, which signaled that the contents of the room were unusually well-preserved. Then I heard her call me: "Glenn, there's metal here." I climbed down into the trench to take a look. Two large, lozenge-shaped metal objects were protruding from the soil. Could they be bronze spearheads? One of our colleagues, Sally Dunham, an independent

scholar with a special interest in ancient art, came to the edge of the trench to see what was going on. Why would complete vessels and metal objects be found intact inside a room? "Maybe it's a tomb," she suggested. A few strokes with my brush next to the metal objects revealed part of a long bone. I quickly called over Jill Weber, our zooarchaeologist from the University of Pennsylvania, to have a look.

"Animal or human?" I asked her.

"Human."

We summoned our human skeletal expert, Barbara Stuart of the Beirut Archaeological Center, and she began work on what we now understood to be not a room, but a tomb—and a tomb of substantial size. The bones of an adult soon began to emerge, together with objects that had been buried on or near the body. Around the skeleton's neck were beads and amulets of lapis lazuli, the much-prized blue stone from eastern Afghanistan. One of the

amulets was carved in the shape of a wild goat, with its horns sweeping elegantly backward. Closer inspection of the metal lozenges, our first find, revealed that they were silver, not bronze, and pierced lengthwise, perhaps for stringing as ornaments.

The next morning Stuart began to uncover a second skeleton. At lunchtime she came into our expedition headquarters, thrilled. Next to the second skeleton she had noticed a thin, gold-colored strip in the soil. Her first thought had been, "What ninny dropped aluminum foil into my excavation?" Then she realized the strip was not modern, but an ancient object made of gold. It proved to be a headband, accompanied by gold beads and a gold bracelet.

As the days proceeded, a remarkable story began to unfold. The tomb contained three layers of skeletons, undisturbed, as were the rest of the tomb's contents, in the nearly four and a half millennia since they were buried. Ancient tombs containing gold and silver objects tend to be prime targets for robbers, both ancient and modern, and so a pristine tomb is an exhilarating find. In three subsequent excavating seasons (in 2002, 2004, and 2006) we have discovered that "our" tomb, now designated Tomb 1, was not alone, but was part of a large complex devoted to the burial of high-ranking individuals in the mid- to late third millennium B.C.

We have also found clear signs of sacrifice. Next to the tombs we uncovered five





Tell Umm el-Marra lies in what is now northern Syria, not far from the region bounded by the Tigris and Euphrates rivers—often considered the cradle of civilization. The site may represent the ruins of Tuba, a city first mentioned in cuneiform texts from Ebla.

smaller enclosures of mud brick that contained the bodies of sacrificed animals and, perhaps, sacrificed infants as well. What we call Installation B, for instance, was a six-foot-square, brick-lined subterranean space containing the headless skeletons of two equids (they could be donkeys or Asiatic wild asses—or perhaps hybrids of the two). The bodies had been interred in a standing position; we found the skulls, along with a spouted jar, on a ledge overlooking the skeletons. After the equids had been positioned, smaller bodies were added to the enclosure: two sets of three puppies, as well as a human infant. The other “installations” contained similar interments of equids, sometimes decapitated, often together with human infants, spouted jars, and puppies. In short, the excavations at Tell Umm el-Marra have yielded a rich trove of material and, given the findings, have raised many questions. Our current inquiries are focusing on two issues: how did the centrally placed tombs function in the community, and why was the tomb complex abandoned and eventually covered over?

Tell Umm el-Marra was first excavated in the late 1970s and early 1980s by a Belgian team directed by the late Egyptologist Roland Tefnin. Those investigations determined the sequence of occupations at the site, which was inhabited most intensively during the third and second millennia B.C. Tefnin also uncovered a number of rooms, as well as a city gate on the northeast side.

Hans H. Curvers, an archaeologist at the University of Amsterdam, and I launched our own joint excavations in 1994. From the beginning, our goal has been to investigate the origins and early development of urban civilization in western Syria. In the standard terms of our profession, we are investigating Bronze Age times, roughly between 3000 B.C. and 1200 B.C. That period, following the widespread adoption of agriculture, is notable not only for the advent of bronze metallurgy (as its name implies), but also for the emergence of writing and, in general, an increase in social stratification. Early urban life in Mesopotamia, the region between the Tigris and Euphrates rivers that some consider the “cradle of civilization,” has been well examined, but archaeologists still have a lot to learn about developments in western Syria.

Tell Umm el-Marra, the largest site in the Jabbul Plain, probably functioned as a regional center throughout the Bronze Age [see map on this page]. It may have been the city known as Tuba, which is first mentioned in texts dating from around 2400 B.C. that were discovered in Ebla, a much larger city to the southwest. Whatever its name in ancient times, though, it was strategically positioned. To the east was a dry steppe frequented by pastoral nomads and, beyond them, the Euphrates River. To the west were rainy agricultural lands, along with the major city of Aleppo. Hence Umm el-Marra probably controlled east-west trade between Aleppo and the Euphrates, and likely served as a trading hub in its own right.

Our first few field seasons concentrated on two 400-year-long periods, the Late Bronze Age (1600–1200 B.C.) and the Middle Bronze Age (2000–1600 B.C.). Then came the unexpected discovery of our tomb, which dated from 2300 B.C., in the Early Bronze Age. The skeletons in the early tomb had been buried in three layers, inside rectangular wooden coffins. Few traces of wood remained, but the shape and material of the coffins was apparent from impressions left in the soil and other residues.



Gold pendant, shown two times actual size, was among the many ornaments discovered in the upper layer of Tomb 1.

In the topmost of the three layers were the two bodies, placed side by side, that Barbara Stuart had first exposed, females between fifteen and twenty years of age [see photograph on pages 42–43]. Each of them had the skeleton of an infant placed at the knee, and around the bodies were costly objects—beads, disks, and pendants of gold; silver bracelets; gold and silver pins used to fasten clothing; a bronze torque, or circular neck ornament; and scores of ceramic vessels.

In the second layer, below the two women, were two men, also placed side by side, and a baby at some distance away near the tomb entrance [see photograph below]. Those skeletons appeared to have been interred at the same time as the women, but in contrast with the women, the men were buried with relatively few objects—just a bronze dagger and spearhead, a silver headband, and a silver bracelet. Finally, the lowest layer held the body of a single adult, probably a woman, who had apparently been

buried earlier, because her bones had been much disturbed by the interment of the men above. A few objects, including a small silver cup and some silver pins, were found with her bones.

The remains posed an intriguing puzzle. Why were the bodies of two richly adorned women of about the same age, each with a baby, placed above two relatively “poor” men? Perhaps the women were of high rank—princesses or priestesses—and they were accompanied in death by lower-ranking men. The men might have been servants or guards who had been sacrificed to escort their mistresses into the afterlife. That kind of human sacrifice was not unknown in the period: archaeologists who excavated tombs in the royal cemetery of the city of Ur, in southern Mesopotamia, found evidence of slain attendants, and there may be another example of such sacrifice at Tell Banat, a Syrian site on the Euphrates. Or, more mundanely, perhaps the four



Middle layer of Tomb 1 contained the skeletons of two men (above) and an infant (not shown), apparently buried at the same time as the two women buried above them (see photograph on pages 42–43). Beneath the men's skeletons were earlier remains, of another adult.



Gold and silver pins for fastening clothing were recovered from Tomb 6. They are shown three-quarters actual size.

adults and three babies had succumbed all at once from natural causes, such as an epidemic.

In our excavating seasons since 2000, six more tombs have been exposed, dating from between 2500 B.C. and 2200 B.C. Most of them, unfortunately, were disturbed in antiquity. Subsequently, however, the entryways were blocked with boulders, and so the interiors have still yielded informative remains. Each tomb contained the bones of at least two people, and pottery (useful for dating) was abundant, including many intact vessels. In some cases, as in Tomb 6, we found additional artifacts, including vestiges of a wooden coffin, gold and silver pins, bronze daggers, and beads of lapis lazuli, gold, and a quartzlike, reddish-brown stone known as carnelian.

But the prize among the new tombs was Tomb 4, which had not been seriously disturbed. In our excavation we found Tomb 4 had two levels, and in the deeper (and thus older) of the two, the skeletons of two adult females and one adult male lay in repose. The women had ornaments next to their bodies, including silver pins and squares of gold with lattice designs. Pierced, pointed objects made of ivory were found with both sexes; we tentatively interpret them as hair ornaments. Two miniature tables carved from basalt, which we discovered stacked one on top of the other, may have served as surfaces for grinding cosmetics. And in the northwest corner of the tomb we were surprised to find a pair of eyes staring out at us from the soil that filled a small square shaft—eyes of stone and shell of the kind used for inlays in statuary. They may have belonged to a small statue of wood or other material that rotted away long ago.

The second, upper level of Tomb 4 also held three bodies: an adult male, an

adult female, and a child. Once again, as in Tomb 1, the woman's body was the most elaborately outfitted. It is unlikely that the costlier grave goods accorded to women signified that women held greater wealth or status than men. Texts from the same period make it clear that men wielded the greater political and economic power. Perhaps upper-class women of ancient Umm el-Marra were simply more likely to wear ostentatious jewelry than were their male counterparts—as is common in our own society. A woman's showy accoutrements

may thus have advertised the wealth or prestige of her family or her husband.

Near the woman in the upper level of Tomb 4 we also discovered seven silver vessels. They are similar in shape to metal vessels found in the royal cemetery of Ur, suggesting that the elites of Syria were imitating the styles of their Mesopotamian counterparts (and maybe vice versa). Owning luxury goods in exotic styles or from exotic places was presumably a good way to display one's high status.

One of the most provocative questions was what to make of the skeletons of animals and infants associated with the tombs. Our conclusion was that rituals featuring animal sacrifice and perhaps even human infant sacrifice accompanied the burials of

the adults in the tombs. So who were those adults? I have little doubt that they were the highest-ranking members of their community. Contemporaneous texts from Ebla reveal that high-ranking people were buried with elaborate jewelry of the kind we excavated. In fact, if Umm el-Marra was presided over by independent rulers, the tombs may qualify as royal. At the very least, the individuals buried within them were once members of powerful families.

The sacrificed donkeys or wild asses would have been objects of prestige: contemporaneous texts from Ebla and elsewhere state that such animals drew the war wagons of the elite, and that they were costly. Perhaps the sacrificed animals were intended to transport the deceased to the afterlife, or to serve them in it. Why infant sacrifice was conducted—if it was—is harder to explain. Human sacrifices often accompanied elite burials in such early urban societies as Dynasty I of Egypt, the Shang period of China, and in the Ur



Clay cylinder, perforated lengthwise and covered with what appears to be some form of writing, is one of four discovered in the upper level of Tomb 4, dating from ca. 2350 B.C. It is shown three-quarters actual size.

royal cemetery, perhaps as a display of raw power.

The tombs also probably acted as constant reminders of the importance of the deceased. After all, they were conspicuous objects in the community—centrally placed, raised up, and at least partly freestanding. The descendants of the dead, by making offerings at the tombs of those interred, may have acquired and maintained their own prestige. Ritual texts from Ebla, which describe offerings made to deceased kings by the living ruler, support that interpretation. In Mesopotamia, by contrast, royal tombs such as the ones at Ur were subterranean and well hidden, suggesting that ancestor veneration was less central, ideologically as well as spatially.

Judging from the small number of bodies in each tomb and the changing styles of pottery, we also infer that power and prestige shifted from one family dynasty to another fairly quickly, in as little as a generation or two. As I noted earlier, many of the tombs were disturbed and then had their entryways blocked with boulders. Groups that attained power may have desecrated the tomb of their predecessors, thereby destroying the link between the living community and the family that was out of favor.

It is unlikely that the perpetrators were either ordinary robbers or family members of the deceased. First, it seems unlikely that robbers would have taken the trouble to block the doorways on their departure. Second, if the tombs had been plundered by robbers, then resealed by community members who valued the interred people, an effort would have been made to tidy things up inside the tombs. But the interiors were left in disarray.

Around the end of the Early Bronze Age, about 2000 B.C., many Syrian cities shrank in size or were abandoned altogether. The reason for the apparent collapse is a subject of vigorous debate. Some point to abrupt climatic change, others to human-induced environmental degradation. We have studied both botanical and faunal remains for clues, but so far we have no satisfactory answer. What we can say is that parts of Umm el-Marra were abandoned, and many nearby settlements were deserted as well.

Then, around 1800 B.C., there was a resurgence of the community, probably related to the rise of a powerful kingdom based at Aleppo. An energetic program of public works was undertaken at Umm el-Marra, including new earth and cobble ramparts

encircling the site and a mudbrick city wall on top. In that same era, the “acropolis” was enclosed with its thick wall, and the tombs were covered over by the heap of rocks I had found so disappointing.

In the fourteenth century B.C., Umm el-Marra fell victim to an episode of substantial destruction: some buildings were burned, with some of their household implements, luxury items, and other contents still inside. The timing suggests a link with the onslaught on western Syria by King Suppiluliuma I, whose domain was centered in Boghazkoy, in present-day Turkey. By 1200 B.C.,



Bones of an infant (lower left) and of a donkey or Asiatic wild ass (upper right) were found in a compartment near tombs 1 and 3. Both the infant and the animal may have been sacrificed, evidence of the high rank of those interred in one or the other of the tombs.

the end of the Late Bronze Age, Umm el-Marra was abandoned, at least as a city. Although no one has yet proved that Umm el-Marra was the site of the city of Tuba, that period is also the latest in which Tuba is mentioned in ancient texts.

The mound on the Jabbul Plain was reoccupied from time to time thereafter, most substantially between about 500 and 200 B.C. Those who came that late, however, would not have known about the tombs, by then hidden and forgotten. The people buried within were left for archaeologists to discover. In a way, then, we are the first who can restore to them a small measure of the glory they once claimed. □

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Groovestem Indian plantain grows amid low hills in a remnant of Louisiana prairie.

Uncommon Property

In northern Louisiana, soil with an ancient link to the sea invites a unique flora.

By Robert H. Mohlenbrock

When I visited Louisiana in late April of last year, I asked Scott D. Edwards, a plant-use specialist, what part of his state boasted the most unusual flora. Edwards, then in the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS), replied without hesitation: "The Copenhagen Hills Preserve." And so one morning he drove me and his colleague Terry G. Johnston to the preserve, not far from

the small community of Copenhagen in northern Louisiana.

As we climbed out of his pickup truck we found ourselves in a dry forest on top of a narrow ridge. To the east, a series of 300-foot hills rose one after the other before us, part of a small upland area known as the Bayou Dan Hills. The preserve, Edwards told me, extended eastward four miles along the Ouachita River. Totalling about 1,500 acres, the property was once owned in part by the

International Paper Company and in part by the late John McKeithen, governor of Louisiana from 1964 until 1972. But the steep slopes made logging difficult, and after the paper company learned of the region's botanical significance, it sold its share to the Nature Conservancy in 1999. The rest was bequeathed by the former governor, who died that same year. Because of its botanical sensitivity, the preserve is open to visitors by permission only [see "Visitor Information" on opposite page].

Hills of any kind are exceptional areas in Louisiana, which is otherwise flat. Three main hilly zones—the Kisatchie and Nacogdoches wolds (hills) and the Ouachita Hills—extend through the north of the state. They began forming tens of millions of years ago, as rivers carried silt from the north and deposited it into the

Prairie Big bluestem, Indian grass, little bluestem, side-oats grama, and switchgrass are the principal grasses. Common prairie wildflowers include black-eyed Susan, hairy laspedeza, lanceleaf tickseed, and prairie blue-eyed

grass. Rare ones for Louisiana include eared goldenrod, false boneset, groovestem Indian plantain, Nuttall's rayless goldenrod, prairie bluets, prairie parsley, prairie pleatleaf, purple coneflower, purple prairie clover, smooth oxeye,

white prairie clover, and yellow pimpernel.

Ridgetop woods Blackjack oak and post oak are the dominant trees, but pignut hickory and shagbark hickory are also common. Shorter trees include

fragrant sumac, roughleaf dogwood, and winged elm. Downy phlox is the most abundant spring-blooming wildflower; several asters and goldenrods dominate the fall landscape. Yellow jessamine is the common vine.



VISITOR INFORMATION

The Nature Conservancy of Louisiana
P.O. Box 4125
Baton Rouge, LA 70821
225-338-1040
318-412-0472
www.nature.org/wherewework/northamerica/states/louisiana/

sea. With time the layers of sediment built up and became compressed, transforming into clay, sandstone, and shale. As newer deposits were added along the coast, they weighed down those geological formations, or rock layers, tilting them down in the south. That slow tilting caused the layers farther north to rise. As streams arose, they eroded the uplifted formations, creating low hills and shallow valleys.

In the Bayou Dan Hills (which might be considered part of the Ouachita Hills), that same tilting elevated a geological formation known as the Jackson Group, which is rich in marine fossils. According to a USDA-NRCS

Stream flows through bottom woods between shallow slopes.

Slope woods boast numerous species of hickories and oaks, and several kinds of buckthorns, elms, and maples. The oaks include diverse-leaved oak (a rare hybrid of laurel oak and blackjack oak), Durand's oak, and Oglethorpe oak.

American beech, cucumber tree, flowering dogwood, nutmeg hickory, sweet gum, and tulip poplar are among the other trees. Wildflowers rare in Louisiana include spiked crested coralroot, Walter's violet, and whiteleaf leather flower.

survey, the soil that developed from that formation includes small particles of calcium carbonate (CaCO_3), as well as shells of mollusks, coral, and other fossils. Outcroppings of the Jackson Group formation do occur in other areas, however, so it is not the sole basis for the unusual flora in the preserve. According to Charles Guillery, a soil scientist at USDA-NRCS, an important contributing factor is that prairie habitat was widespread there in the past, creating acidic conditions that leached most of the calcium and magnesium out of the soil. In addition, he suggests, the steep slopes and the erosive action of the Ouachita River, both of which have contributed to churning and moving the soil, may also have made it unique.

From the ridgetop where we parked, my companions and I headed eastward along an abandoned dirt road, descending the first of many steep slopes we would encounter that day. Near the base of the slope was a nearly treeless expanse of land blanketed by grasses: a remnant of Louisiana prairie. The habitat has been nearly extirpated from the state. The grasses we saw were mostly spe-



Bottom woods Wetland species grow wherever a stream flows along the base of a slope. Trees include bald cypress, river birch, Shumard oak, swamp chestnut oak, swamp hickory, sycamore, and water hickory. Among

the shrubs are American snowbell, possumhaw, eastern swamp privet, and spicebush. Vines that climb high into the trees include American wisteria, climbing dogbane, ladies'-eardrops, and supplejack.



Fossils found in Copenhagen Hills soil, which developed from rock layers formed under the sea

cies characteristic of prairies north and northwest of Louisiana.

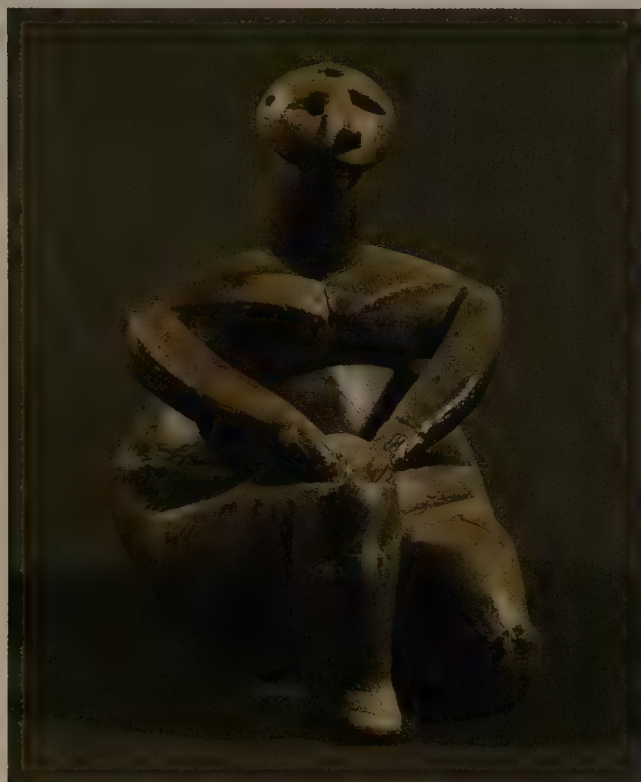
The slopes above the prairie were wooded, and as we explored them and other wooded slopes, I was impressed by the great diversity of species and the presence of many plants not generally found in Louisiana. I was also surprised to find some places with upland species such as chinquapin oak and southern red oak growing side by side with bottomlanders such as Shumard oak and swamp chestnut oak.

In our one-day survey of Copenhagen Hills, the three of us recorded eighty-seven species of trees, twenty-six kinds of shrubs, and twenty species of woody vines—133 woody species in all. Numerous nonwoody species made our list as well. But there must be even more: the happy thought is that only further visits in other seasons could make our tally reasonably complete.

ROBERT H. MOHLENBROCK is distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.

*The Invisible Sex:
Uncovering the True Roles
of Women in Prehistory*
by J.M. Adovasio, Olga Soffer
and Jake Page
Smithsonian Books; \$26.95

Surely the title of this book is a bit hyperbolic. Judging by their place in popular culture, prehistoric females were far from invisible. After all, the best-known australopithecine is Lucy, the diminutive hominid whose 3.2-



Statuette of a sitting woman, made of polished terracotta and found near Cernavodă, Romania, dates to the end of the fourth millennium B.C.

million-year-old skeleton was uncovered in Ethiopia in 1974. And what of Ayla, the Cro-Magnon heroine of Jean M. Auel's blockbuster, *The Clan of the Cave Bear*, and its sequels?

Still, the prehistoric archaeology of *Homo sapiens*, like most academic fields, has historically been dominated by men. It's not surprising, therefore, that, in the museum dioramas, textbooks, and popular literature produced by these august gentlemen, Stone Age people are generally represented as tribes of skin-clad cavemen who hunted mammoth, bison, and giant bears and

sat around chipping spear points in their spare time. Women may not have been invisible, but traditional archaeologists did not regard them as central to Paleolithic and Neolithic culture. In the canonical story of human prehistory, men were the shamans, men invented atlatls and digging sticks, men created the exquisitely conceived paintings on the walls of hidden caves.

When women did appear front and center, they assumed an exaggerated sexual role. The famous Venus of Willendorf, a buxom statuette discovered in an Austrian riverbank in 1908, became the archaeological archetype of a Stone Age fertility goddess. Many similar figures discovered since have conventionally been described as avatars of the passive role of women: the bearers of children, the embodiment of hearth, home, and sedentary life.

Yet to J.M. Adovasio, an archaeologist, Olga Soffer, an anthropologist, and Jake Page, a science writer, the Venus statuettes symbolize, at most, the ambiguity in the evidence for women's place in prehistoric society. After all, they argue, the societal significance of many artifacts from the distant past is not immediately obvious. For all we know, the statuettes may have served as religious icons, children's playthings, or sex toys.

Thus it would be as presumptuous to attribute too much power to prehistoric women as it would be to attribute too little power to them. New Age feminists like to cite the work of the Lithuanian-American archaeologist Marija Gimbutas, who saw the Venus figures as evidence for a pervasive matriarchal society that dominated the prehistoric scene in Europe. But after years of academic debate about the evidence, the case for pacific matriarchal societies remains

as fragmentary and contradictory as the case for male-dominated packs of hunters. It's likely that Edenic clans of goddess worshippers led by Wicca priestesses are more common in California today than they ever were in Neolithic Europe.

That said, the authors offer up some less ambiguous evidence that women's roles in developing culture were at least commensurate with those of men in several important areas. Women, according to the authors, had an important part to play in the agricultural revolution. Just as important, though perhaps less well appreciated, women in both ancient and modern cultures have been the ones involved most directly in producing textiles.

Stone, of course, is more durable than cloth. But in dry caves and other places where textiles dating to the Upper Paleolithic (some 26,000 years ago) have been preserved, spun and woven artifacts outnumber stone artifacts by a ratio of twenty to one. Imprints of textiles and basketry have been found that date back tens of thousands of years. If the authors are right, the loom ought to appear along with the stone-tipped spear in those museum dioramas, and the "String Age" ought to be given equal billing with the Stone Age.

*The Sun Kings:
The Unexpected Tragedy
of Richard Carrington and the Tale
of How Modern Astronomy Began*
by Stuart Clark
Princeton University Press;
\$24.95

Around the time Bostonians were sitting down to Sunday dinner on August 28, 1859, all the equipment at the State Street telegraph office suddenly went dead. To the west, at the telegraph depot in Springfield, Massachusetts, a huge spark leapt from incoming wires, filling the office with acrid smoke. In Pittsburgh, Pennsylvania, telegraph operators panicked when "streams of fire" began to burst

from their receivers. As night fell, observers from Canada to the Bahamas reported intense auroral displays in the heavens, some so bright you could read newsprint out-of-doors. Compass needles swung wildly, as if the Earth itself was trembling, and nearly a week went by before the auroras disappeared and electrical communication returned to normal. Science journalist Stuart Clark calls the event "the perfect solar storm," caused by an immense ejection of electrically charged particles from the Sun. It was the most intense magnetic storm in recorded history.

Few people, however, suspected the true nature of the event at the time. A few earlier observers had reported compass disturbances that coincided with auroras. In the early 1800s the English astronomer William Herschel had noted that the price of wheat rose as the number of reported sunspots fell, suggesting that solar activity might affect climate. But the data were sketchy,

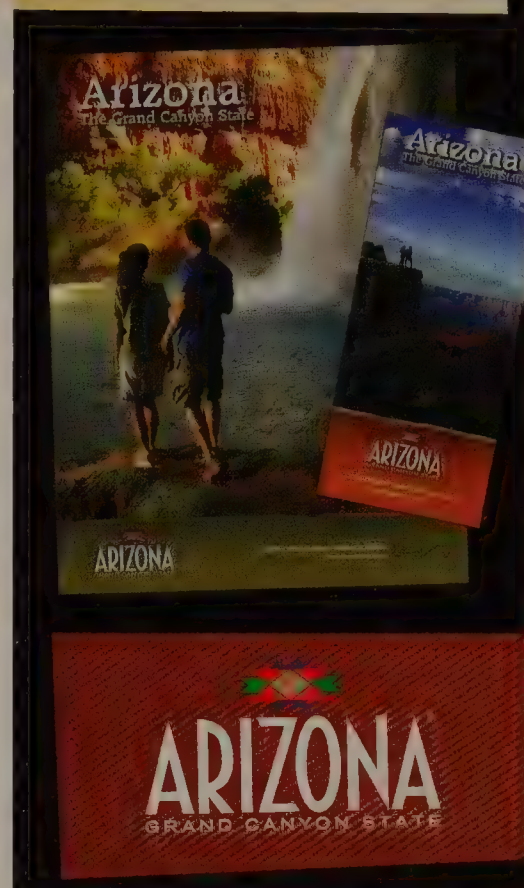
and the forces that could stir up the Earth across 93 million miles of empty space were completely mysterious.

In 1859, however, one notable observer was keeping track of the Sun's activity. Richard Christopher Carrington, a wealthy amateur and member of the Royal Astronomical Society, had been carefully sketching the Sun, as it appeared through his own specially designed telescope, on every clear day since November 1853. Captivated by the idea that fundamental solar cycles might underlie the processes of nature, Carrington hoped that by systematic long-term observation he could uncover the laws that governed solar activity.

On September 1 of that year, a few days after the great magnetic storm began, he was surprised by two brilliant, white fireballs that moved across the solar surface at a speed he later calculated to be more than 400,000 miles

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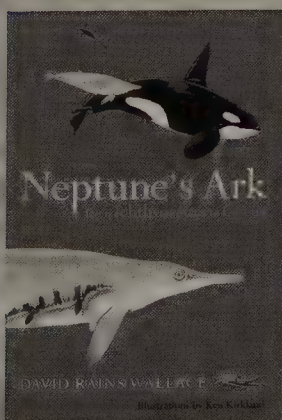
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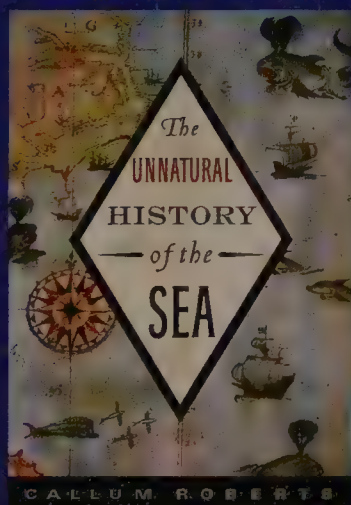


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an hour. Nothing like them had ever been seen before. In London, while traveling on business, he learned that magnetic sensors at Kew Observatory had recorded a large swing in their compasses coinciding with the fireballs on the Sun. It was the first direct evidence that solar storms generated magnetic lines of force that reached across space to Earth.

That, of course, was only the beginning of a story that continues to this day. Until the mid-1800s, astronomers had devoted themselves almost exclusively to measuring positions of objects in the sky. But the techniques of Carrington and his contemporaries gave birth to the new science of as-

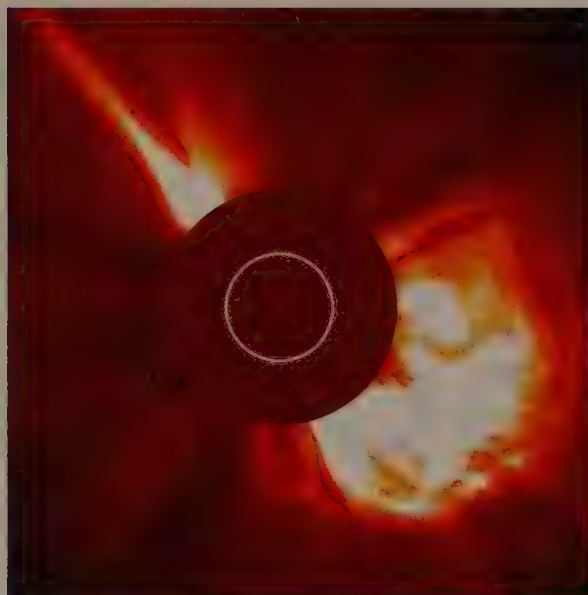
led to a Gothic imbroglio of bigamy and assault. He died too soon to appreciate how much light he had brought into the world.

*The Wild Trees:
A Story of Passion and Daring*
by Richard Preston
Random House; \$25.95

North of San Francisco, not far from the California-Oregon border, lies a hidden valley where two monumental redwoods—nicknamed the East and West spires—stand side by side. If you had looked up from between their massive trunks on the morning of December 8, 2001, you would have seen two people suspended from ropes high overhead, both wearing climbing harnesses, and one a bridal veil. As an airborne minister officiated and several intrepid guests watched from adjacent treetops, Marie E. Antoine and Stephen C. Sillett exchanged their wedding vows.

Antoine, Sillett, and their friends are members of a subculture that finds challenge and enlightenment several hundred feet off the ground, clambering among the topmost branches of the world's tallest trees. The intrepid investigators are mapping and cataloging the biological diversity of one of the few remaining unexplored habitats on Earth: the forest canopy of the American Northwest. Antoine, who lectures at Humboldt State University in Arcata, California, is an expert on *Lobaria oregana*, or lettuce lungwort, a spongy lichen that flourishes in the high branches of old-growth Douglas-fir forest. Sillett, a biologist who is also at Humboldt State, climbed his first redwood on a lark in 1987, and is now recognized as a world expert on the ecology of the coastal-redwood canopy.

Antoine and Sillett, as respectable academics, have made high-tree climbing a source of livelihood, but most



Largest solar flare ever recorded, sixteen minutes after peak emission, November 4, 2003

trophysics, which can probe questions about the structure, function, and origin of the stars, planets, and the universe at large. Now the click of a mouse yields "Today's Space Weather" (www.sec.noaa.gov/today.html), which provides close-up images of the Sun in near-real-time, along with various up-to-date measurements of solar activity such as particle fluxes, auroras, and the strengths of magnetic fields. From Carrington's observations, Clark spins a lively account of seminal discoveries in spectroscopy, photography, and theoretical physics that led to the present-day understanding.

Carrington, alas, ended his own life after his marriage to a young woman



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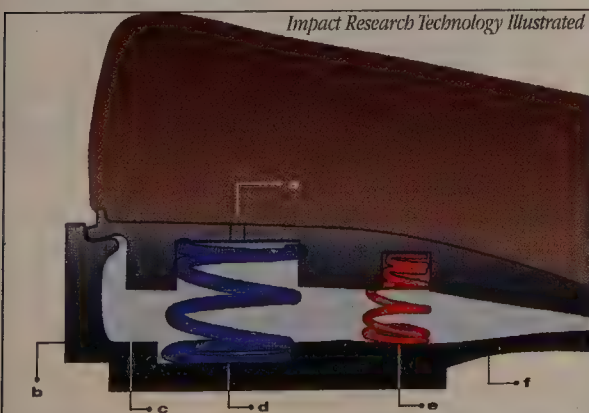
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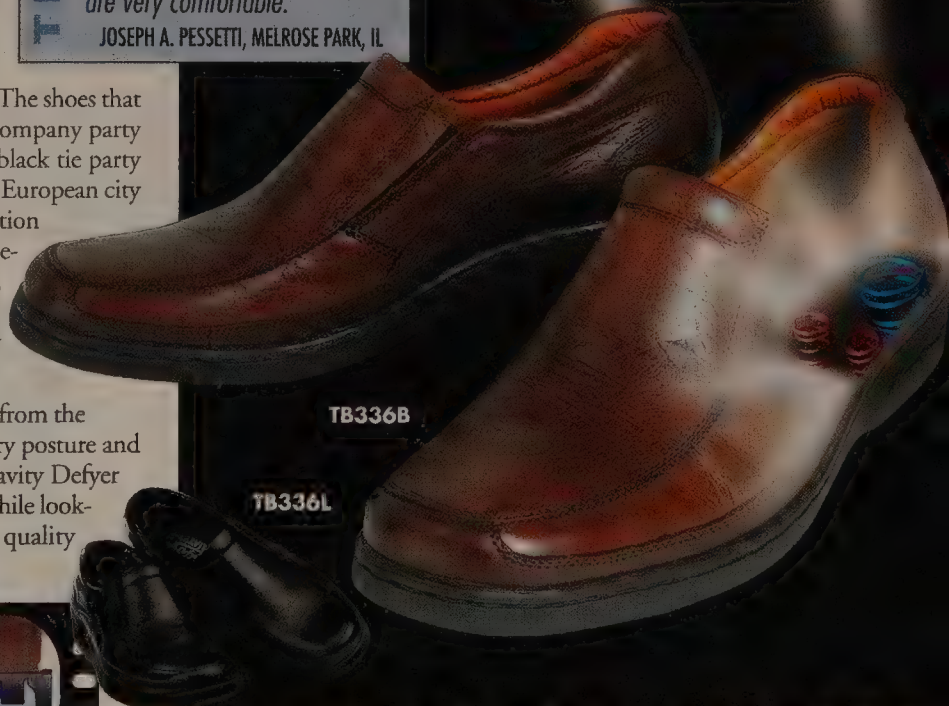
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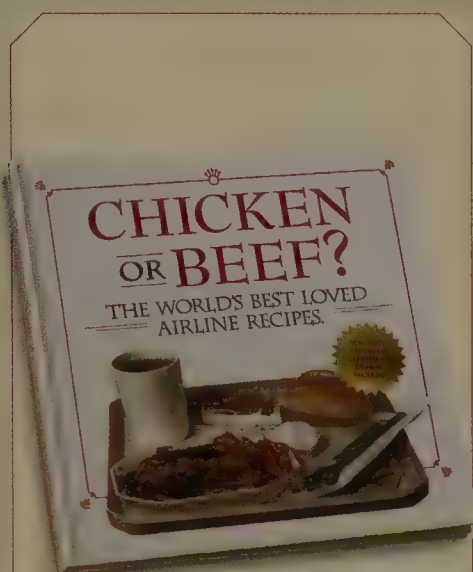
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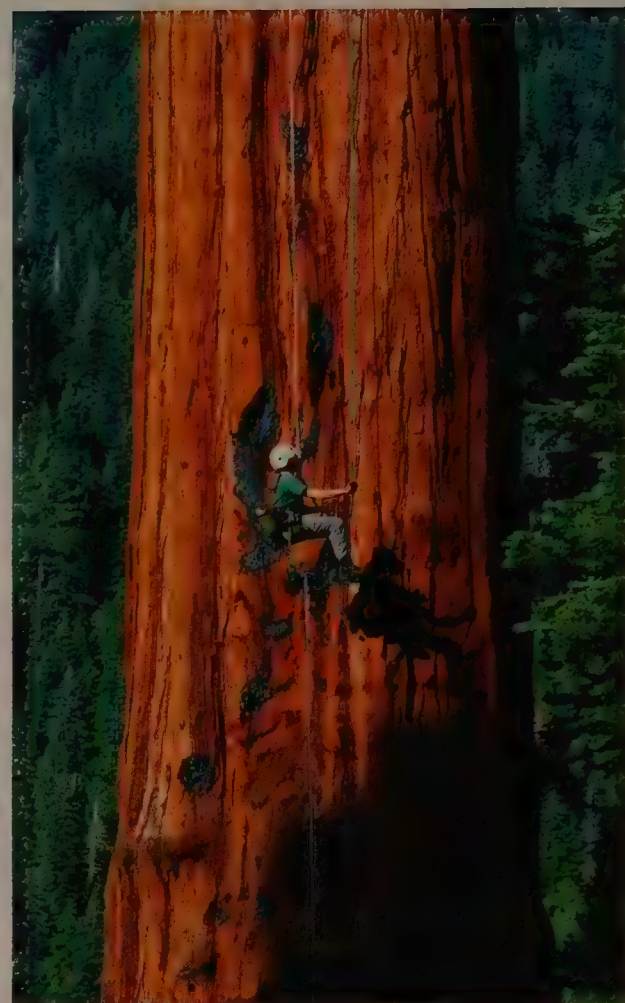
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of the canopy crew ascend just for the fun of it. Today's recreational climbers have adapted techniques first developed by tree surgeons (professionally known as arborists), cavers, and climbers to shoot ropes into the highest branches, ascend and lower with rope clamps and rappel racks, and string up networks of lines from limb to limb from which they can suspend. Like rock climbing, it's a demanding and precarious sport, but an expert tree climber can move as gracefully 200 feet up as a ballet dancer on terra firma.

Such grace, perhaps, is not surprising, since our distant primate ancestors were more at home in the trees than on the ground. What is surprising is that Richard Preston is one of the climbers himself. A best-selling author, he's known for his spellbinding accounts, both fiction and nonfiction, of deadly viruses and bioterrorism: *The Hot Zone*, *The Demon in the Freezer*, *The Cobra Event*. But in recent years, he's taken to the trees, practicing first near his home in New Jersey, and later in California and Australia (where the swamp gum, *Eucalyptus regnans*, rivals the redwoods in height). He's climbed with such veterans as Sillett and Antoine, listened to their stories of near-death falls and exhilarating aerial adventures, and applied his gift for research to learning all he can about the giants of the forest.

Natural-history buffs may be tempted to approach this retelling with a yawn. Redwoods have been the darlings of the literati since at least the days of John Muir. We all know they are huge, dignified, and ancient. But, thanks in large part to the work of high climbers, we now know much more than is evident from the ground. Preston informs us, for instance, that it takes two weeks for water to travel from the roots to the top of a redwood. He notes that redwoods also gather water



Rope climber is dwarfed by a giant redwood.

directly into their needles by absorbing water from fog. And he explains how organic material, a kind of aerial potting soil, collects in the tangles and crotches of the canopy, where climbers find colonies of worms, thickets of elderberries, huckleberries, and rhododendrons, and a lichen whose common name is fairy puke.

As far as I could tell, there is no Ebola or smallpox high in the redwoods: perhaps Preston started climbing as a respite from the terrestrial horrors he wrote about in the past. But that doesn't mean his latest effort is a let-down. *The Wild Trees* is the intelligent sort of nonfiction readers have come to expect from him, a book that elevates, entertains, and, alas, is over far too soon.

LAURENCE A. MARSCHALL, author of The Supernova Story, is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.

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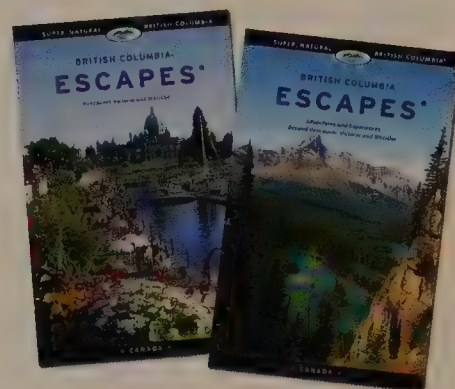
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Life's Patterns

By Robert Anderson

Through mathematics one can enter a purely abstract world—one that I recently rediscovered while reading *The Number Devil*, by the German author Hans Magnus Enzensberger, to my children. With wonderful illustrations by Rotraut Susanne Berner, the book takes readers into the surreal dreams of a troubled math student who is visited nightly by an irritable teacher with a pointing cane, red skin, and horns. Together, student and teacher venture into territory rarely explored by the schools, which confine themselves to the materials covered by standardized tests. The Devil unveils a rich world in which the numbers form curious patterns, almost as if they were alive.

The big surprise is that even the most arcane realities of abstract mathematics often end up offering deep insights into the natural world. In 1960 the physicist Eugene P. Wigner published his classic paper, "The Unreasonable Effectiveness of Mathematics in the Natural Sciences" (www.dartmouth.edu/~matc/MathDrama/reading/Wigner.html). Going beyond his title, Wigner makes the point that "the enormous usefulness of mathematics in the natural sciences is something bordering on the mysterious and that there is no rational explanation for it." Einstein's famous formula, $E=mc^2$, is just one example of how the natural world can be neatly reduced to equations.

There are many sites that show some of the innovative ways that mathematics can help illuminate the living world; to see my review of some of the best of them, please go to our *Natural History* Web site (www.naturalhistorymag.com), click "Online Extras," then "Web Links," and finally "May 2007" to find "nature.net."

ROBERT ANDERSON is a freelance science writer living in Los Angeles.

Mercury reaches superior conjunction, behind and roughly in line with the Sun, on May 3rd. It passes the point of its orbit closest to the Sun (its perihelion) on the 8th, and quickly enters the evening sky. By the night of the 10th it sets fifty minutes after the Sun and shines at magnitude -1.5 , just a trifle brighter than Sirius, the brightest star in the sky. The planet, in hues of topaz, can be picked up in binoculars. Look for it far to the lower right of Venus, near the west-northwest horizon; Mercury is the brightest starlike object in its part of the sky.

Mercury becomes easy to see with the naked eye after midmonth. It sets near the close of evening twilight. On the evening of the 17th Mercury is close to the horizon and about two and a half degrees to the lower left of a young crescent Moon. Although slowly fading, the little planet gains altitude rapidly day by day. By the 27th it climbs to within twenty-two degrees of Venus (your clenched fist held at arm's length is roughly ten degrees wide). Then, for about the next ten days, the two planets seem to stay almost fixed in their respective positions above the dusk horizon.

Venus is the brightest evening "star" in the west; at a dazzling magnitude of -4.2 , it is bright enough to show through the blue sky soon after sunset. Appearing at its greatest height in the evening twilight for 2007, the planet stands nearly forty degrees above the western horizon at sunset. By the third week of the month it's setting in the northwest shortly before midnight local daylight time (LDT). On the evening of the 19th, Venus and the crescent Moon make a stunning celestial tableau as they descend the western sky side by side, less than a degree apart. Planetariums—and police precincts—will likely get a few calls inquiring about the "UFO" hovering next to the Moon! By month's end Venus is within several degrees of Pollux and Castor, the bright stars in the constellation Gemini, the twins. Telescopic viewers can observe Venus

becoming larger and its crescent thinner as it swings around from the far side of the Sun toward the Earth.

Mars rises within about a half hour of the first sign of morning light. Look for the orange first-magnitude object low in the east as dawn brightens. It moves eastward this month, and crosses from the dim stars in the constellation Aquarius, the water-bearer, into the similarly dull constellation Pisces, the fish, on the 9th. It also passes to the south of the Great Square of Pegasus.

Jupiter is the brilliant light pushing its way up into the southeast sky during the evenings. The giant planet rises around 10:45 P.M. LDT as May begins. By month's end it is rising around 8:30 P.M. and is already above the horizon as darkness falls, shining at magnitude -2.5 . To its right or lower right is Antares, the red first-magnitude heart of the constellation Scorpius, the scorpion. The entire "fishhook" of the scorpion is extracting itself almost straight up from the horizon to Jupiter's right.

Saturn appears as a yellowish-white "star" of magnitude $+0.4$, about eleven degrees west (to the lower right) of Regulus, the brightest star in the constellation Leo, the lion. Saturn is more than halfway up in the southwest sky as darkness falls. It sets around 2:45 A.M. LDT on the 1st and a couple of hours earlier by month's end. At midmonth, a thirty-power telescope shows the famous ring system tilted about fifteen degrees from our line of sight.

The **Moon** is full on the 2nd at 6:09 A.M. Our satellite wanes to last quarter on the 10th at 12:27 A.M. and to new on the 16th at 3:27 P.M. The Moon waxes to first quarter on the 23rd at 5:03 P.M. A second full moon takes place on the 31st at 9:04 P.M. The second full moon in a calendar month is sometimes referred to as a "blue moon."

Unless otherwise noted, all times are eastern daylight time.

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INVESTMENT MANAGEMENT**18. CALVERT-INVESTMENTS THAT MAKE A DIFFERENCE®**

The nation's largest family of mutual funds that integrate rigorous financial analysis with a thorough assessment of corporate integrity including environmental impact.

MARYLAND**19. CARROLL COUNTY**

Quaint villages, festivals, scenic biking and hiking. Antique shops, country inns, and our Civil War Driving Tour. Just 45 minutes northwest of Baltimore.

20. CHARLES COUNTY

It's for the birds! Take a hike! Hunt for fossils, golf, fish, shop. Experience the wild side of the Potomac where eagles soar.

21. CHESAPEAKE BAY MARITIME MUSEUM

Located in historic St. Michaels, the Museum boasts ten waterfront exhibits, working boat yard, and the largest collection of Bay boats.

22. CHOOSE CALVERT COUNTY

Less than an hour from D.C. discover Chesapeake Bay history. Hunt along sandy beaches for over 600 fossil species at the 15-million-year-old Calvert Cliffs.

23. DORCHESTER COUNTY

Home to world-renowned Blackwater National Wildlife Refuge; explore the heart of Chesapeake Country on Maryland's Eastern Shore.

24. FREDERICK COUNTY

Maryland's Crossroads of History. Antiques, battlefields, covered bridges, parks, wineries and more close to Gettysburg and DC.

25. KENT COUNTY

A scenic peninsula on the Chesapeake Bay, offering fishing, boating, kayaking, small beaches, great shopping, and museums.

26. MARYLAND VACATIONS

Beaches, mountains, big cities, small towns. Maryland has so many things to do, so close together.

27. MONTGOMERY COUNTY

Experience transportation history along the C&O Canal and the National Capital Trolley Museum. So many things to do.

28. ST. MARY'S COUNTY

Potomac River lighthouses, Chesapeake Bay seafood, and maritime history. Quaint towns, scenic byways, and tidewater trails. Cozy inns, waterside dining and fantastic festivals.

29. TALBOT COUNTY

Five beautiful rivers, 602 miles of shoreline, unique charming hamlets St. Michaels, Oxford, Tilghman Island and Historic Easton offer a timeless treasury of natural beauty & history.

30. WORCESTER COUNTY

Maryland's only seaside county. Visit Assateague Island National Seashore. Kayak, canoe, bird watch or golf, bed and breakfast inns.

MONTANA**31. CUSTER COUNTRY**

Custer, Sitting bull, and Lewis and Clark have been here. Why haven't you?

32. HELENA

Experience the charm, culture and limitless outdoor adventure in Montana's capital city. Order your Free Travel Planner today.

33. MONTANA TOURISM

Montana—Play, relax, and explore in our untouched, picturesque, serene yet wild landscapes. Find what you're looking for in Montana. Free Vacation Planner.

34. MONTANA'S MISSOURI RIVER COUNTRY

An unspoiled land offering wildlife, Old West history, Lewis & Clark attractions, dinosaur museums and more. Free Travel Planner.

35. MONTANA'S RUSSELL COUNTRY

Legendary in the paintings of yesterday and the digital pixels of today.

U.S. TRAVEL**36. ALABAMA GULF COAST**

Spectacular beaches. Outstanding accommodations. And warmed by sunshine, history, culture and unspoiled natural beauty.

37. ARIZONA—THE GRAND CANYON

Grab life and seize the day. Immerse yourself in a day full of adventure and a night full of fun.

38. LITTLE ST. SIMONS ISLAND

Exclusive 10,000-acre Georgia island paradise, private 7-mile pristine beach, natural history tours, birding and recreational activities galore.

39. NORTH CAROLINA OUTER BANKS

The Outer Banks of North Carolina—Immerse yourself in culture and history. Here anytime is quality time.

40. SOUTHWEST LOUISIANA

Filled with exotic wildlife, captivating flora, fishing, natural wetlands and nature trails topped off with authentic Cajun cooking. Come enjoy!

41. TUCSON

Tucson, Real. Natural. Arizona.

Discover a new side of nature in our fascinating desert landscape. The weather's perfect for exploring our spectacular scenery any time of year.

At the Museum

AMERICAN MUSEUM OF NATURAL HISTORY



www.amnh.org

The Stuff of Dreams

Early European sailors told of sirens and sea serpents, monsters that made their way onto ancient maps at a time when terra incognita still denoted uncharted lands. Medieval tapestries recorded images of unicorns, and the literature of the Middle Ages is replete with knights in search of dragons. Today, moviegoers flock to see Gollum in *The Lord of the Rings* and children are delighted by Harry Potter's hippogriff and Disney's little mermaid, Ariel. Fact or phantasm, sometimes even a little of both, such beings are as old and enduring as imagination itself.

Here to explore the anthropological origins and cultural significance of some of the world's most enchanting mythological characters is the American Museum of Natural History's new exhibition *Mythic Creatures: Dragons, Unicorns, and Mermaids*, on view from May 26 through January 6, 2008. The exhibition can truly be called fabulous fun for the whole family. It highlights such supposed denizens of land, sea, and air as dragons, griffins, mermaids, sea serpents, and unicorns, with models that have to be seen to be believed, among them a 17-foot-long dragon; the mythical bird of prey, the roc, with a 19-foot wing span; and a kraken, the multi-armed, ship-foundering sea monster, its massive two-foot-diameter tentacles surfacing all through the hall.

Fantastic creatures have been part of human experience for thousands of years, passed down through legends and fables, ancient and contemporary art, performances, and even in the accounts of early naturalists. *Mythic Creatures* will showcase sculptures, paintings, textiles, and other cultural objects from around the world ranging from representational shadow puppets and ceremonial masks to a spectacular Japanese samurai suit of armor that bears the image of a dragon as a symbol of the wearer's power.

Mythic Creatures will also investigate how some fossils, through misidentification, speculation, and imagination, could have been taken as proof of the existence of legendary beasts. Visitors will learn, for example, how Scythian nomads,

East Asian dragons, like the one portrayed by this 19th-century Chinese shadow puppet, are the underwater equivalent of kings and emperors, reigning over watery realms.



D. FINNIN/AMNH

on their quest for gold in the Gobi Desert, were likely to have come across dinosaur bones that would have bolstered their belief in the existence of the gold-guarding griffin, a legendary creature with the body of a lion and head and wings of an eagle, often portrayed on heraldic shields and coats of arms.

In a reverse twist, some tales of undersea monsters may have resulted from glimpses of living sea creatures that are just as fantastic as any imaginary beast, including the giant squid and the oarfish. Even the curious manatee is said to have inspired the report by Christopher Columbus in Haiti in 1493 that mermaids were "not as pretty as they are depicted, for somehow in the face they look like men."

Mythic creatures are the product of human imagination, and this exhibition will bring to light surprising similarities—and differences—in the ways peoples throughout time and across cultures have envisioned and represented these strange and wonderful beings, telling us as much about the people who imagined them as about the creatures themselves.

The exhibition is co-curated by Mark Norell, Curator in the Division of Paleontology; Laurel Kendall, Curator in the Division of Anthropology; and Richard Ellis, Research Associate, and is designed and produced by the American Museum of Natural History's Department of Exhibition.



D. FINNIN/AMNH

This mid-18th-century *netsuke* (an often intricately carved toggle used to fasten a small container to a kimono sash) portrays a *tengu* (a Japanese mythological bird) emerging from a giant egg.

Mythic Creatures: Dragons, Unicorns, and Mermaids is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with The Field Museum, Chicago; Canadian Museum of Civilization, Gatineau; Australian National Maritime Museum, Sydney; and Fernbank Museum of Natural History, Atlanta.

Mythic Creatures is proudly supported by MetLife Foundation.

Amphibious Invasion

The halls are alive with the sound of, well, chirp, trill, croak, and gribbet! That's right, back for a repeat engagement is one of the most enchanting and popular exhibitions in the Museum's recent history: *Frogs: A Chorus of Colors*, on view from May 26 through September 9.

This captivating collection of more than 200 live frogs from around the world, shown in re-created habitats, complete with rock ledges, live plants, and waterfalls, is the perfect introduction to the colorful and richly diverse world of frogs.

Among the many adorable encore favorites are the tiny golden mantella frog, which is bright red and less than an inch long, the pale green waxy monkey frog, and the Vietnamese mossy frog whose camouflage is so effective it's fun try-

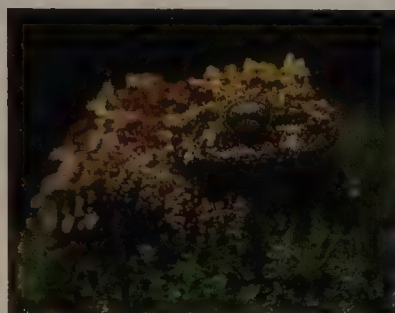
ing to find one among many in a mass of moss. A dart poison frog vivarium remains a centerpiece of the exhibition, while interactive stations throughout invite visitors to hear recorded frog calls, view videos of frogs in action, and test their knowledge about frogs.

The exhibition explores the evolution

and biology of these diminutive amphibians, their importance to ecosystems, and the threats they face in the world's changing environments, and features the latest research findings on frogs, reflecting the ongoing work con-

ducted by scientists in the Museum's renowned Department of Herpetology and their colleagues around the world.

Frogs: A Chorus of Colors is presented with appreciation to Clyde Peeling's Reptiland. *Frogs* is made possible, in part, by the Eileen P. Bernard Exhibition Fund.



The Vietnamese mossy frog is a camouflage expert.

JOE McDONALD
CLYDE PEELING'S REPTILAND

PEOPLE AT THE AMNH

Jeanne Kelly

Supervisor of Fossil Preparation
Division of Paleontology



ENRICO FERRELLI

Finding Jeanne Kelly's office within the warrens of the staff-only floors of the Museum is to be reminded that behind the public exhibition halls is a working research institution with more than 200 scientific personnel. It's also not hard to believe that the Museum houses perhaps the most important fossil collection in the world, and Jeanne ensures that the specimens are ready for study, storage, and display.

"My happiest moment is going into the collection, drawer after drawer, can after can," says Jeanne, who describes fossil prep as "a juncture between art and science."

Researchers cannot study what they cannot see, after all, and, for many of her 32 years—first as a volunteer, then part-time, then staff—Jeanne's job was to carefully chip away the matrix surrounding fossils brought from the field to the lab. Her specialty was tiny mammals, early insectivores, working under a microscope with miniature jackhammers and carbide needles to expose teeth and inner ear regions on specimens as small as one-half inch.

Between 1990 and 1996, Jeanne moved from the micro-world to the macro- for the renovation of the fossil halls on the fourth floor during which "every specimen was moved, cleaned, and remounted." She is now codirector of a similar undertaking, the transfer of the fossil mammal collection, some 400,000 specimens, as seven storage floors in the Childs Frick Building are refurbished. It's a huge job, but Jeanne is used to that from her experience in the dinosaur halls. "You don't move an *Apatosaurus* easily!"

DIORAMAS IN YOUR DEN

WWW.AMNH.ORG

Longing for another look at the Cuthbert Rookery or in need of an Alaskan Brown Bear fix? The Museum's world-famous habitat dioramas and the fascinating stories behind them are at your fingertips at www.amnh.org/dioramas. You will be transported to a treasury of images and information about the explorers, naturalists, painters, sculptors, taxidermists, and conservationists who fused art and science into the three-dimensional marvels that have captivated children and adults alike for generations.

At the site, you will find 360-degree panoramic virtual tours of four favorite habitat dioramas, hall highlight videos, and a downloadable MP3 audio tour for your next visit, led by Stephen Quinn, the Museum's Exhibition Project Manager and author of *Windows on Nature: The Great Habitat Dioramas of the American Museum of Natural History*. Moreover, the site offers instant access to a unique collection of archival photos as well as profiles of the artists and taxidermists who brought the dioramas to life. Give yourself plenty of time to savor the experience—just as you would at the Museum itself.



D. FINNIN/AMNH

The two-story Andros Coral Reef diorama in the Milstein Hall of Ocean Life

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY 

www.amnh.org

EXHIBITIONS

Gold

Through August 19, 2007

This glittering exhibition explores the captivating story of the world's most desired metal. Extraordinary geological specimens, cultural objects, and interactive exhibits illuminate gold's timeless allure.

Gold is organized by the American Museum of Natural History, New York (www.amnh.org), in cooperation with The Houston Museum of Natural Science. This exhibition is proudly supported by The Tiffany & Co. Foundation, with additional support from American Express® Gold Card.



H. DAVIES/AMNH

Clipper butterflies

The Butterfly Conservatory

Through May 28, 2007

Visitors mingle with live, free-flying butterflies in a tropical environment.

Undersea Oasis:

Coral Reef Communities

Through January 13, 2008

Brilliant color photographs capture the dazzling invertebrate life that flourishes on coral reefs.

Beyond

Through April 6, 2008

Exquisite images from unmanned space probes take visitors on a journey through

the alien and varied terrain of our planetary neighbors.

The presentation of both *Undersea Oasis* and *Beyond* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

GLOBAL WEEKENDS

Explore the cultures of the world with live musical performances, films, discussions, and more.

Asian American Heritage

Saturday, 5/12

2:00 p.m. The Triangle Project's *Journey of the Dandelion* explores peace and unity through drumming, singing, and movement.

4:00 p.m. KaWaDa Ensemble, a trio of Japanese and Mongolian musicians, performs *As the Wind Blows*, created specifically for this event.

This program is cosponsored with the Asian American Arts Alliance.

In Celebration of Indigenous Peoples

Saturday, 5/19, 1:00–4:30 p.m.

Live Native American musical performances and discussions with representatives from the United Nations and indigenous peoples.

Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, the New York City Council, and the New York City Department of Cultural Affairs.

Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

LECTURES

Sea Dragons

Tuesday, 5/8, 7:00 p.m.

Richard Ellis discusses the lives, deaths, reproductive habits, and hunting strategies of giant prehistoric marine



ED COHEN

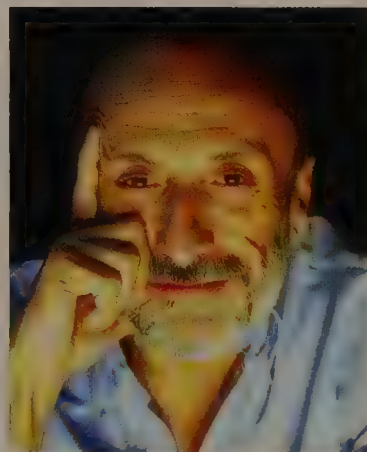
Yoko Fujimoto, Nobuko Miyamoto, and P.J. Hirabayashi are the Triangle Project.

reptiles such as *Ichthyosaurus*, *Mosasaurus*, and *Plesiosaurus*.

Slow Food Nation

Tuesday, 5/15, 7:00 p.m.

Carlo Petrini, founder of the Slow Food organization, explains how we can improve our health and the health of the planet and offers models for reforming the way food is grown, prepared, and eaten.



SLOW FOOD/ALBERTO PEROLI

Carlo Petrini, originator of the Slow Food movement

ADVENTURES IN THE GLOBAL KITCHEN

LECTURES AND TASTINGS

Bees and Their Honey

Tuesday, 5/8, 7:00 p.m.

Honey has been used for thousands of years for everything from flavoring food and beverages to curing illnesses.

Research entomologist Diana Sammataro discusses the history of the cultivation and uses of honey, and presents different varieties to taste.

Exquisite Mushrooms

Tuesday, 5/15, 7:00 p.m.

Mushrooms can be tasty, medicinal, or even deadly. Focusing on the tasty varieties, author Gary Lincoff and chef Amy Farges will transform the way you view the not-so-lowly fungi.



ROSE CENTER FOR EARTH AND SPACE

Sets at 6:00 and 7:30 p.m.

Friday, May 4

Michele Rosewoman and Quintessence

All about Wine

Tuesday, 5/29, 7:00 p.m.

Vintner and wine judge Louisa Thomas Hargrave discusses the history of winemaking and current trends in production and consumption.



WORKSHOP

Making Gold-Wire Jewelry

Sunday, 5/20,

10:00 a.m.–4:00 p.m.

Gold wire has been used in jewelry making since antiquity. Honey Jeanne Laber and Marsha Davis guide students through basic gold-wire

techniques used in creating earrings, pendants, bracelets, and necklaces.

FAMILY AND CHILDREN'S PROGRAMS

NEW! Alien Workshop

Sunday, 5/20, 11:00 a.m.–

12:30 p.m. (Ages 4–5,

each child with one adult) and

1:30–3:00 p.m. (Ages 6–7,

each child with one adult)

Can life exist on other planets? Children participate in experiments that might help answer that question and take home their own “alien.”

AstroFavorites: The Earth and Space Collection

Thursdays, 5/10, 17, and 24

4:00–5:30 p.m. (Ages 4–6,

each child with one adult)

A discounted series of astronomy workshops: Earthly Adventures, Solar System Adventures, and The Sun and Its Energy on three consecutive Thursdays.

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m.,

or visit www.amnh.org. A service charge may apply.

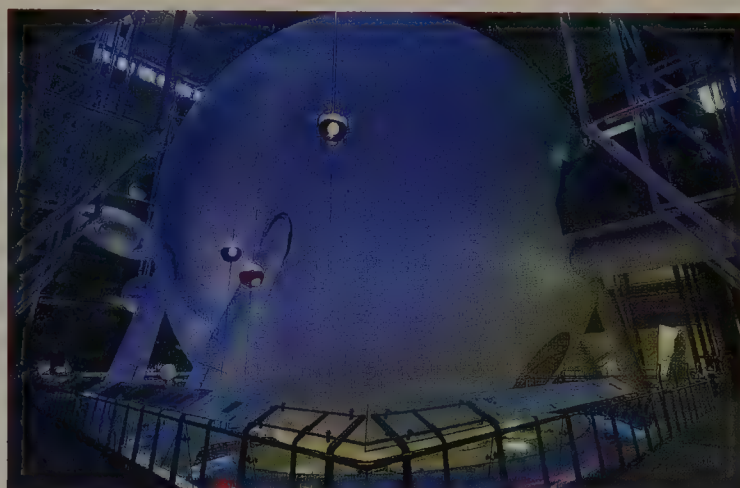
All programs are subject to change.

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

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The Hayden Planetarium

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe

Out of This Galaxy

Tuesday, 5/1, 6:30–7:30 p.m.

Celestial Highlights

Parade of Planets

Tuesday, 5/29, 6:30–7:30 p.m.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions

Journey into deep space—well beyond the calm face of the night sky—to explore cosmic collisions, hypersonic impacts that drive the dynamic forma-

tion of our universe. Narrated by Robert Redford.

Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum. Made possible through the generous support of CIT. *Cosmic Collisions* was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

SonicVision

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ENDPAPER

Where Eagles Swim

By Annie Prevost

Enormous, swiftly moving dark wings first catch my eye, then a white head and a tail, as I walk along Mineral Point on San Juan Island, Washington. Bald eagle—the thought flashes through my brain—diving like a missile after a seagull. I am riveted by the pair. The eagle misses, rises, turns sharply, and plunges again; the hapless gull doesn't stand a chance. Into the ocean they both tumble. Repeatedly the eagle goes underwater as the gull fights for its life. Other agitated seagulls dive-bomb the eagle, and a lone crow joins the fray.

Soon enough, the struggle ceases. Then slowly, with great effort, the eagle begins flapping its six-foot-wide wings through the water, not heading skyward, but swimming, towing its quarry toward shore. When soaring in the sky, an eagle is the crowning symbol of effortless power and speed. The swim I am watching, though, is flight in slow motion—ponderous, laborious, anything but effortless.

Now the eagle appears to be barely moving. To reach the shore it must swim the length of two football fields placed end to end. With the gull clutched in its talons, it moves as though it's dragging a sea anchor. Won't fatigue and hypothermia set in? And won't the long swim consume as many calories as the seagull will provide? Yet the eagle perseveres. The other birds disperse, and I won-

der whether I will have to watch all afternoon to see the eagle finish its swim to shore.

Two years earlier, I watched a similar scene unfold from my mother's waterfront condo in West Vancouver, British Columbia. That day, too, an unusual motion in the water caught my eye. Grabbing binoculars, I saw an eagle floundering and thrashing at the surface. Not yet knowing that eagles could swim, I thought the bird was drowning. Then I saw that it was trying to lift a large white object, what I guessed to be a dead seagull. Soon the eagle gave up and with a mighty flap rose from the water with empty talons. But before I could put down the binoculars, it swooped back to the water's surface with enough momentum to grab its catch and fly off in triumph.

I've since learned that eagles have a hard time raising their wings once they're in the water. That's why, instead of attempting a liftoff, they swim considerable distances to shore. Perhaps they'd rather face a long

swim than abandon their catch.

When I look again at my San Juan eagle, I'm surprised to see how much progress it has made in ten minutes of swimming. Even without binoculars I can see its erect white head and white tail fanned out over the ocean surface, as it steadily muscles those great wings through the water. It swims with both wings in sync, a butterfly stroke without the benefit of a leg-driven dolphin kick.

About fifty feet from shore the eagle suddenly takes flight, rising into the air while the seagull floats limply in the water. But not for long. I should have guessed from my earlier sighting: the eagle circles, swoops down, and hooks the prey. Then, like an overloaded bomber, it flaps heavily away, the gull dangling from its talons like a sack of flour. The eagle, I would guess, has been in the water between fifteen and twenty minutes.

I move for a better view, in the hope of seeing it land. Across a small bay atop some steep rocks I spot the familiar dark brown and white form. I strain to see the white head moving up and down as it feeds. And I imagine I can just make out the gull's white feathers fluttering down the rocks. If only I had my binoculars.

ANNIE PREVOST is a writer and a keen observer of the natural world who lives in northwest Washington.

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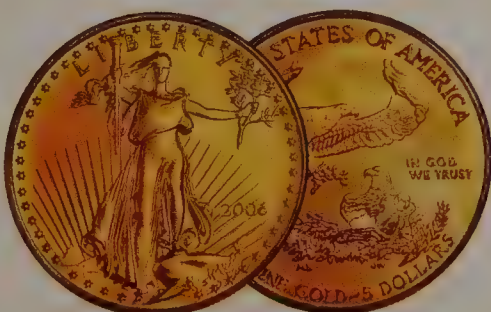
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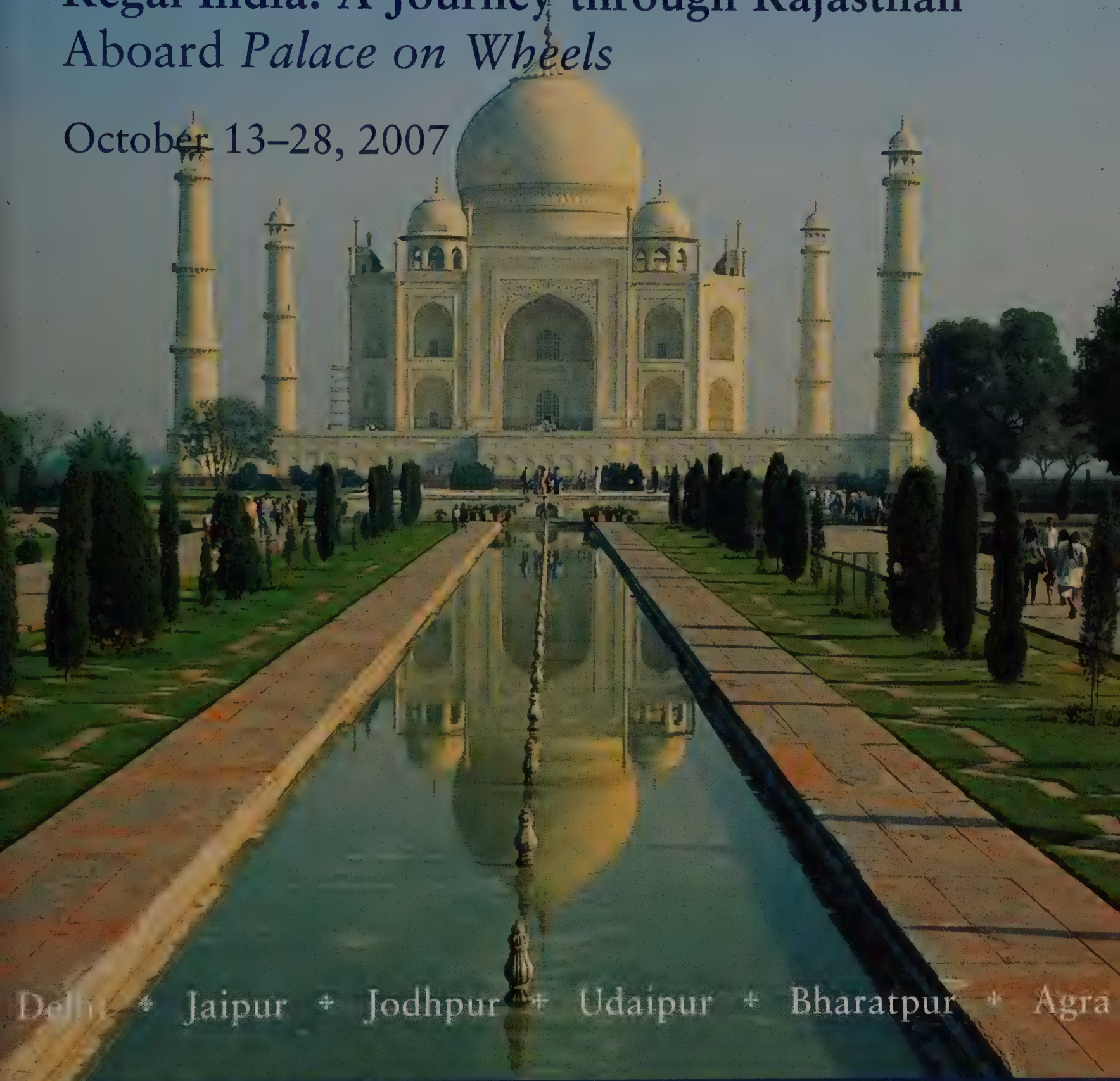
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NATURAL HISTORY

6/07



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In 1983, at the invitation of China's Ministry of Health and university medical centers, Project HOPE became the first private international health organization to make a long-term commitment to improving that vast nation's healthcare system.

Recently, Project HOPE's China Diabetes Program was launched to increase both public and professional awareness of diabetes and improve the quality and availability of diabetes care. To learn more, visit www.projecthope.org.



Partners in health

More than 30 million people in China are living with a disease they know little or nothing about. Diabetes, known for decades in many countries as the "silent killer," rapidly has become a major chronic disease for the Chinese.

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Diabetes Care, 2004, World Health Organization

America's Most Admired Companies, annual survey, 2007, FORTUNE magazine, March 19, 2007

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NATURAL HISTORY

JUNE 2007

VOLUME 116

NUMBER 5

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La Brea continues to bubble over with new clues about life that flourished 40,000 years ago, where Los Angeles is today.

JOHN M. HARRIS



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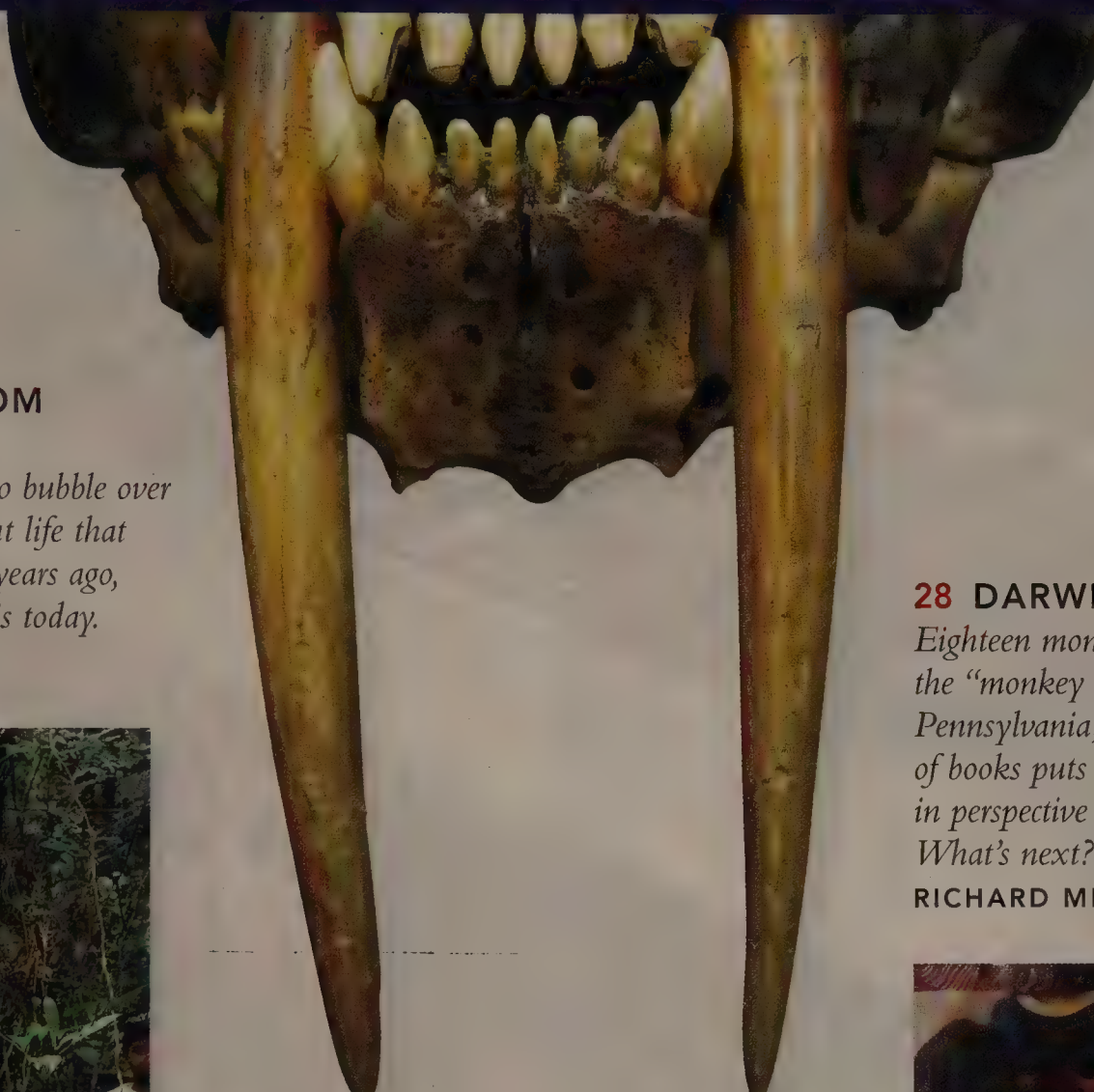
The forests of southern Bahia, Brazil, threatened by development, shelter numerous rare plants, which botanists are racing to document before they disappear.

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Eighteen months after the "monkey trial" in Dover, Pennsylvania, a bumper crop of books puts the battle in perspective and asks, What's next?

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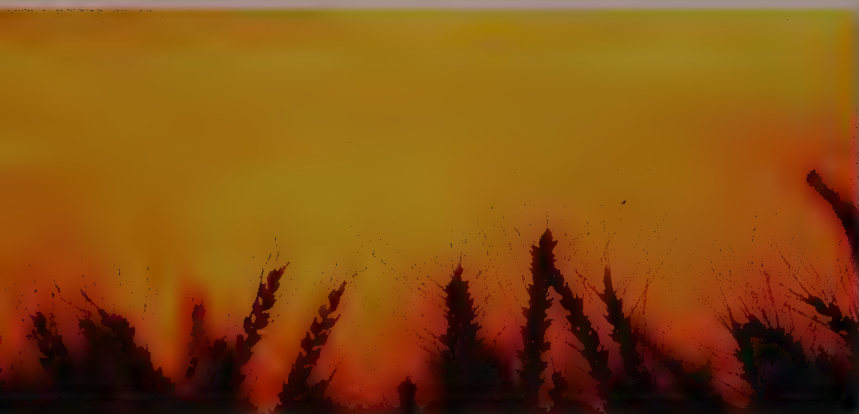
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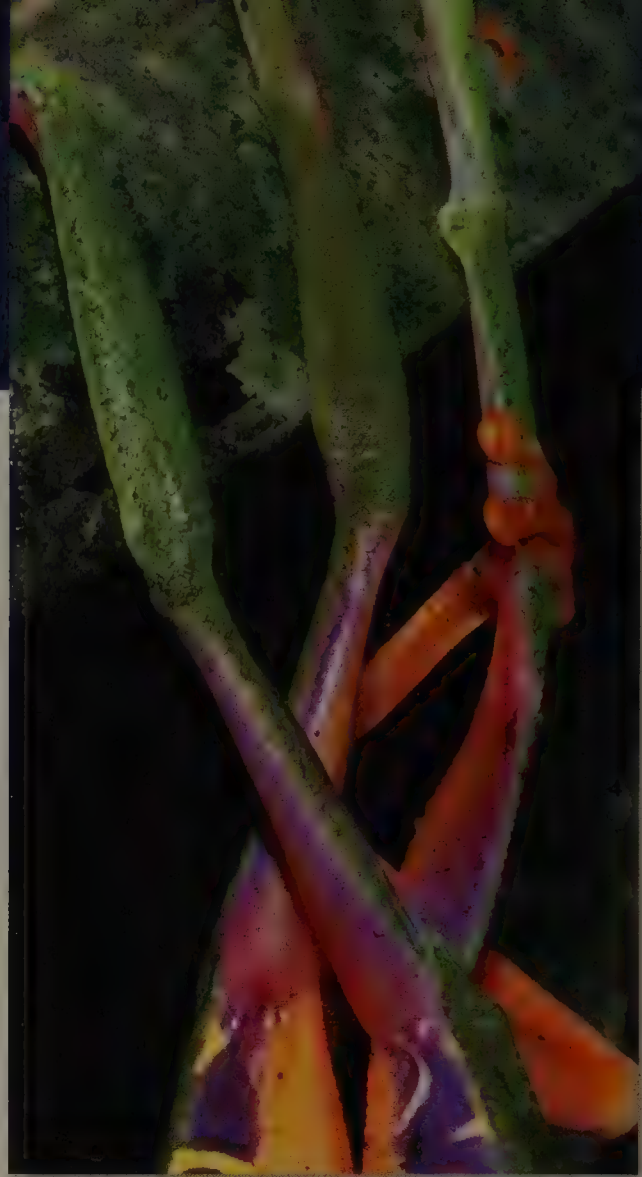
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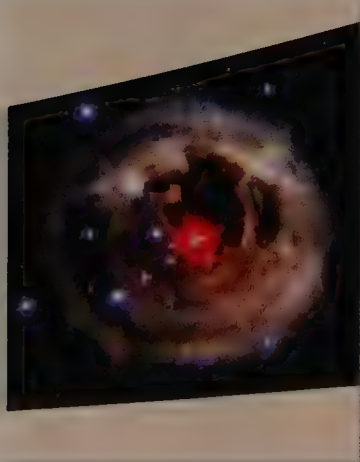
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ON THE COVER: Mask of Barong Ket, a lionlike creature. In Balinese dance ritual, the mask is considered to be inhabited by a spirit.



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THE NATURAL MOMENT

Toe Hold

Photograph by Kevin Schafer

◀ See preceding two pages

When the first heavy rains of spring drench Costa Rica, a certain league of suitors begins fighting. Think WWF, as in Wild Wrestling Frogs. Here, two male red-eyed tree frogs (*Agalychnis callidryas*) put a hold on each other unmatched even by the most pumped-up pro wrestlers: dangling upside down, belly to belly, they wrap their arms around each other's heads and gouge their sticky, orange hands into crimson eyes.



Photographer Kevin Schafer had heard about a seasonal breeding pool for *A. callidryas* on Costa Rica's Caribbean coast, but no one had prepared him for what he stumbled upon one night in early June. Dozens of frogs were out in colorful view, calling raucously for mates. Schafer described the scene as "a wild amphibian orgy."

Frogs not locked in upside-down combat were doing their best to engage in another kind of embrace. Males were grasping females around the abdomen and not letting go. Sometimes a male holds on for days, as he fends off other suitors and even as his mate dives underwater to fill her bladder and wet her eggs.

Finally, after fertilization, the female lays her eggs on leaves that hang over the water, to keep the eggs temporarily safe from hungry fish. But what about other predators? Recent observations show that the growing tadpoles can distinguish among vibrations—sensing a difference between, say, a strong gust of wind and a snake—and so control when to take the big plunge.

—Erin Espelie

Tales from the Tar Pits

The George C. Page Museum in Los Angeles is one of the few museums whose main subject matter is a natural phenomenon that lies virtually underfoot. The Page, a branch of the Natural History Museum of Los Angeles County, was opened in 1977 on the site of one of the most exciting fossil finds of the nineteenth century: the La Brea tar pits. The pits, which are actually pools of asphalt seeping up from an oil field 1,000 or more feet below the surface, have been trapping unwary animals in thick, sticky black goo for more than 40,000 years. John M. Harris, a curator at the Page, describes the pits and their fossil treasures in his article "Bones from the Tar Pits" (page 18).

I spoke with Harris about how museum volunteers take part in the ongoing excavation of Pit 91. "There are two kinds of people who work in the pit," Harris says, "those who remain pristine, and the rest of us who get absolutely covered with tar. You're working fourteen to fifteen feet below the surface, it's hot, and you have to work from crosswalks, with your arms extended" to reach the bones. "In the summer, it's quite physically demanding," he adds, putting it mildly.

The excavators include two full-time staff paleontologists, assisted by volunteers, but no more than eight people can work in the pit at one time. The volunteers are a mix of young and old: students, young professionals, and retired people. One staff member has been excavating at Pit 91 since the current project began: Christopher A. Shaw, the collections manager for the Page, became involved as a student, in 1969, and is now in charge of excavation. "His ambition is to be present when the excavation is finished," Harris told me—perhaps fifteen years from now.

I asked Harris whether anyone had gotten caught in the pit during its modern excavation. No, he replied, but someone once tried to commit suicide by throwing himself into a seep. The attempt was unsuccessful because "the person just stuck to the top like a fly on flypaper, and the fire department got angry because they got their ladders and ropes very dirty."

• • •

Our cover this month pictures a Balinese mask of a Barong Ket, a beneficent spirit creature that, according to legend, protects a village and restores order out of chaos. Spirit creatures are a major focus of a new exhibition, "Mythic Creatures: Dragons, Unicorns & Mermaids," which opens May 26 at the American Museum of Natural History in New York City. Laurel Kendall, one of the curators of that exhibition, describes her own memorable encounter with masks, spirits, and a festival built around them in Vietnam, in her "Endpaper" titled "Eye of the Dragon" (page 48).

• • •

Readers who haven't visited our Web site recently will find a hive of new activity there. We're revamping the design, adding new features, and posting more information than ever about the articles in the magazine. You can download the full audio, for instance, of my interview with John Harris. There's also an archive of selected articles ("Picks from the Past") from 107 years of past issues of *Natural History*. Check it out (www.naturalhistorymag.com).

—PETER BROWN



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Yucatan

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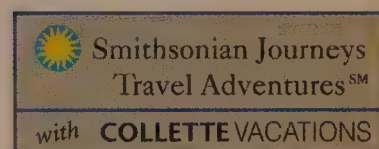
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Conservationist **KEVIN SCHAFER** ("The Natural Moment," page 4) is based in Seattle, Washington, but has traveled extensively—to Costa Rica for this month's photograph of fighting tree frogs, as well as to such faraway places as Madagascar and the Bering Sea—in his quest to document threatened ecosystems. He has written more than ten books illustrated by his photography, including *Penguin Planet* (NorthWord Press, 2000), which received the 2000 National Outdoor Book Award, and *Living Light* (Bitterroot Press, 2006). The North American Nature Photography Association selected Schafer as the Outstanding Nature Photographer of the Year for 2007. Visit his Web site (www.kevinschafer.com) to view more of his photographs.

JOHN M. HARRIS ("Bones from the Tar Pits," page 18) was trained as a geologist and served as the director of paleontology at the National Museum of Kenya before joining the Natural History Museum of Los Angeles County in 1980. He now works there as chief curator of vertebrate studies and oversees the vast collection of late Pleistocene fossils from the La Brea tar pits, housed at the George C. Page Museum. Although he has published widely on La Brea, he is perhaps better known scientifically for his work on East African ungulate fossils associated with the remains of early hominids. He edited a book with the paleoanthropologist Mary Leakey on the fossil footprints of Laetoli, Tanzania, and another with the paleoanthropologist Meave Leakey on the fossil site of Lothagam, Kenya.



Ever since childhood, which he spent in Southeast Asia, **WM. WAYT THOMAS** ("Survival of the Rarest," page 24) has been intrigued by the natural history of tropical forests. As a youngster he focused on things that move, but he soon began to appreciate that plants provide the framework for all other life in a forest. Thomas is the Elizabeth G. Britton Curator of Botany at the New York Botanical Garden, where he studies the conservation and plant diversity of the Atlantic coastal forests of Brazil, focusing on the state of Bahia. He is fascinated with how species are distributed, endemism, and the dynamics of rarity. Thomas also studies the evolution and systematics of the sedge family in the New World tropics.

A Darwin scholar and historian of science, **RICHARD MILNER** ("Darwin in Court," page 28) is an associate in anthropology at the American Museum of Natural History in New York City, and a contributing editor to this magazine. His work for *Natural History* has included editing a special section on Darwin and evolution (November 2005) and, most recently, co-authoring an article on hominid portraits. He is currently working on a book titled *Darwin's Universe: Evolution from A to Z*, which will be published in 2008 by the University of California Press.



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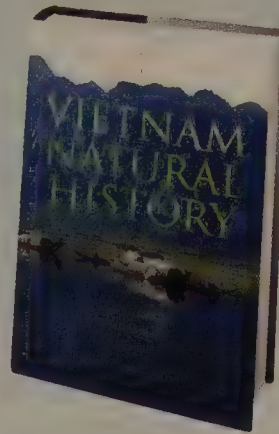
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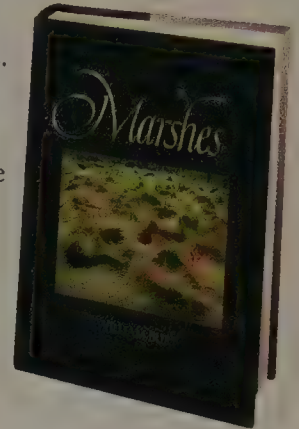
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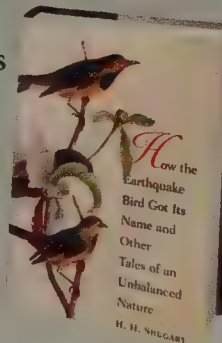


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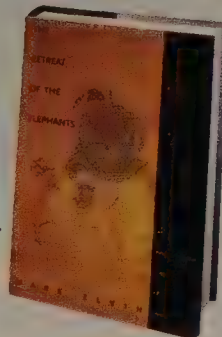
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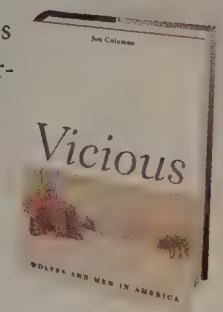
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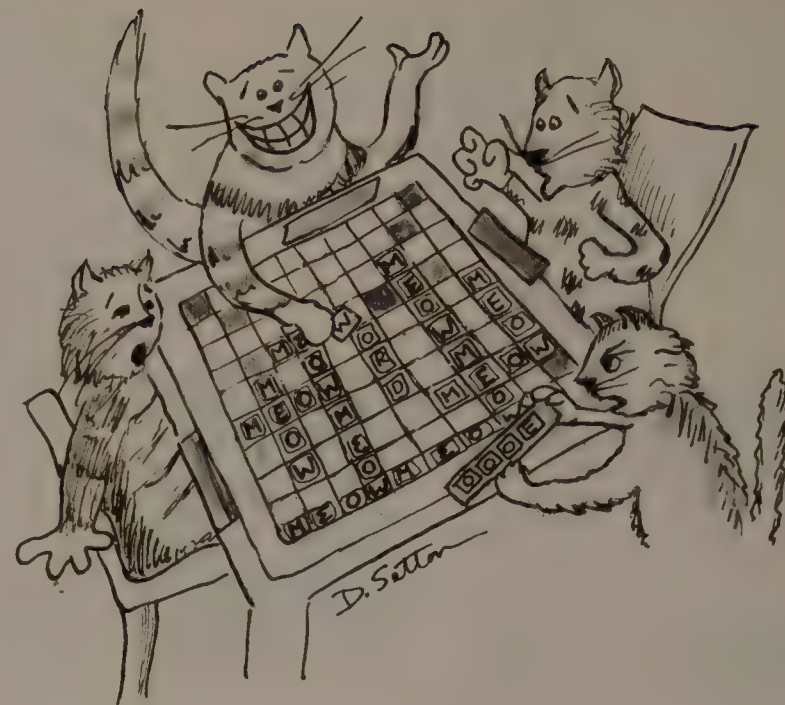
The Play's the Thing

Lynda L. Sharpe's article ["Meerkats At Play," 4/07] was a treat. But I wonder, could play simply be the product of mammalian brainpower? Does one need to play to maintain a more highly developed brain? As a kid, I'd say "I'm bored," and the response would be, "Go outside and play!" In no time, I'd be enjoying myself and discovering things.

C.-A. Thompson
Gloucester, Massachusetts

LYNDA L. SHARPE REPLIES:

C.-A. Thompson's idea is one of the few theories put forward to explain play that is supported by some scientific evidence. There



"Challenge!"

seems to be a correlation between relative brain size and the tendency to play, in birds as well as mammals. And labora-

tory studies have found that young rats develop better learning abilities, heavier cerebral cortexes, and greater neural con-

nectivity when exposed to a complex environment. Sensory stimulation and arousal alone did not affect the rats' brains, but when those factors were accompanied by interactive behavior (as in play), brain growth increased.

Long Life

In "Pregnancy Re-conceived" [5/07], Gil Mor notes that fetal cells reside in the mother decades after her pregnancy, and that those cells can repair maternal tissue. Could that phenomenon help explain why, on average, women live longer than men?

Sondra F. Messina
Fresh Meadows, New York
(Continued on page 42)

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Dental Carries

During their prolonged migration out of Africa, our ancestors were not alone. The cavity-causing bacterium *Streptococcus mutans* went along for the ride, clinging to their teeth. *S. mutans* is transmitted mainly from mother to infant, and so its evolutionary history probably parallels that of its human hosts. A new study takes advantage of the intimate parasite-host relationship to trace the dispersal of *Homo sapiens* across the globe.

Page W. Caufield, a professor of dentistry at New York University, and his colleagues isolated hundreds of *S. mutans* strains collected from the mouths of people on five continents. The investigators compared several segments of DNA from the genomes of thirty-three of the most informative strains. The team then estimated the relatedness of all several hundred strains and built a phylogenetic tree to show their evolutionary relationships.

The tree has its root in central Africa, the homeland of the common ancestor of all *S. mutans* strains—and of their human hosts. A distinct branch extends to Asia, and from there to Europe, representing at least one migratory wave of people who founded a group of modern-day Caucasians. A second African founder population might have reached Europe via a more direct route—possibly through the Middle East. Analysis of additional DNA segments could reveal the host's and the parasite's journey together to other parts of the world. The results support the "out of Africa" theory, which posits a single African origin of modern humans between 100,000 and 200,000 years ago. (*Journal of Bacteriology*)

—Graciela Flores



"Right-mouthed" snake jaw

No Left Turn

With their slender, drab-colored bodies, snakes of the genus *Pareas* seem quite ordinary—until you look them in the mouth. When they open wide, many *Pareas* species display a remarkable asymmetry: in *P. iwasakii*, for example, about twenty-five teeth line the right side of the jaw, whereas only about seventeen line the left. The asymmetry was recently discovered by Masaki Hosoi; his graduate advisor, Michio Hori, an ecologist at Kyoto University in Japan; and a colleague.

The investigators suggested that the reason for the snakes' "right-mouthedness" might be traceable to their diet of snails. The snakes pull snails from their shells by alternately retracting the left and right sides of their jaws. Snail shells usually coil to the right, or dextrally, so having more teeth on the right side could be helpful for the snakes.

To test that idea, the investigators obtained snails whose shells coiled to the left, or sinistrally, then measured the predation success of four *P. iwasakii* snakes on sinistral and dextral snails. The snakes took about twice as long to handle the sinistral snails, retracted their jaws about one-third more frequently, and still succeeded a quarter less often, compared with their attacks on dextral prey.

Sinistral snails tend to be scarce worldwide, but in Southeast Asia and Japan—where the right-mouthed snakes live—they're present in more species. Having evolved a particular jaw dentition to handle the more abundant dextral shells, the snakes may now be exerting selective pressure on snails for more sinistral shells. (*Biology Letters*) —Stéphan Reeb

What Do You Know?

"Is that your final answer?" With such signature lines, TV quiz-show hosts inject drama into their proceedings even as they question the confidence of their contestants. Two investigators at the University of Georgia in Athens recently posed a similar question—to rats. The upshot of their query: rats might not be smarter than fifth graders (to invoke one popular show), but they do know the limits of their knowledge.

Allison L. Foote, a graduate student, and Jonathon D. Crystal, a psychologist, gave six food pellets (a big reward) to rats whenever they showed they could distinguish short sounds from long sounds by pressing the correct one of two levers. (Choosing the wrong lever yielded no reward.) The rats also learned that they could refuse to take a test and instead poke their noses into an opening in the wall of the test chamber to secure a medium reward: three pellets.

Next, the investigators presented the rats with a series of sounds of varying length. The rats seldom declined to press a lever when the sounds were very short or very long. But when the sounds were intermediate in length—and thus harder to categorize—the rats often turned down

the chance at the big reward for the sure bet of a medium reward. In sum, they acted as if they were aware of the limits of their ability. Indeed, when forced to take the test for intermediate-length sounds, they often chose the wrong lever.

Metacognition—the awareness of one's own knowledge—is difficult to study in animals because they cannot respond to questions about what they know. But now, by displaying behavioral signs of metacognition, rats join a select group previously limited to primates and dolphins. (*Current Biology*) —S.R.



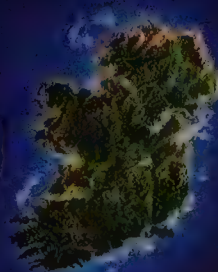


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Follow Your Beak

Homing pigeons and other birds can sense the Earth's magnetic field, an ability that helps them find their way home, even when home is hundreds of miles away. But how this magnetic sense works remains one of the most puzzling questions in sensory biology.

To learn the birds' secret, Gerta Fleissner, a neurobiologist at the University of Frankfurt in Germany, teamed up with physicists and other biologists. Their investigation focused on the skin of the upper beak—where the mysterious magnetic sense is thought to reside. With powerful microscopes they identified three clusters of nerve endings on each side of the homing pigeon's beak, each cluster oriented along one of the bird's three perpendicular axes (beak-tail, wing-wing, and back-belly). Inside the nerve cells they discovered something even more intriguing: two kinds of magnetic iron oxide—square platelets of maghemite and bullet-shaped particles of magnetite. The investigators propose that an extremely delicate arrangement of those intracellular minerals constitutes the long-sought receptor for birds' magnetic sense.

Here's how they think it works: Each pair of clusters (one on each side of the beak) is tuned to detect one of the three perpendicular spatial components of the Earth's magnetic field (north-south, east-west, and up-down). Depending on how closely a pair of clusters aligns with its magnetic-field component, the maghemite platelets in the clusters line up and magnetically attract the magnetite bullets. The rearrangement of maghemite and magnetite in all three pairs of clusters triggers nerve impulses to the bird's brain, enabling the bird to sense the angle and intensity of the local magnetic field—and fly home. Fleissner located similar iron-bearing nerves in several other bird species, and she suspects all birds possess them. (Naturwissenschaften)

—G.F.

Whence the Beef?

Beginning around 800 B.C., the Etruscan civilization developed in what is now Tuscany, in Italy. Its people influenced the founding of Rome at the edge of their territory. Eventually Rome grew, swallowed up its Etruscan neighbor, and went on to greater things.

Scholars have long debated the origins of the Etruscans. Some contend their roots were local; others, such as Herodotus, the fifth-century-B.C. chronicler from Greece, have argued that the Etruscans emigrated from the eastern Mediterranean.

The latter view has now gotten a big boost of modern support. A team of geneticists led by Marco Pellecchia and Paolo Ajmone-Marsan of the Catholic University of the Sacred Heart in Piacenza, Italy, has discovered that the mitochondrial DNA of modern-day Tuscan cattle is much closer to that of Turkish and Middle Eastern bovines than to that of other Italian or European breeds.

Proponents of the local-origin hypothesis might argue that the Etruscans, a seafaring people, simply obtained

foreign cows through maritime trade. But another Italian study, led by Alessandro Achilli and Antonio Torroni, geneticists at the University of Pavia, reveals that modern-day Tuscan people also show genetic similarities to Turkish and Middle Eastern populations. So it looks as if the ancestors of the Etruscans came from the east by sea, bringing their livestock along. "Told you so," Herodotus would say. (*Proceedings of the Royal Society B; American Journal of Human Genetics*)

—S.R.

Virtual Hitchhikers

You can get just about anything online, from a stuffed moose to an acre of the moon. So it goes without saying that seemingly harmless plants can also be added to your e-shopping cart. Online retailers sell them, of course, and enthusiastic gardeners in chat rooms trade the seeds of their favorite blooms.

But all that e-trade could present a growing threat—literally—to biodiversity, according to Yorick Reyjol, an ecologist at the University of Quebec at Trois-Rivières in Canada. Reyjol warns that enabling plants to travel across the planet so freely risks introducing invasive, exotic species to vulnerable ecosystems. Many invasive plants started their destructive journeys as commercial

offerings that were subsequently exchanged among gardeners. (Water hyacinth, a South American plant with attractive purple flowers, is a classic example: it now clogs waterways and chokes out native vegetation across a swath of the United States and in many other nations.) Internet exchanges simply streamline the invasion.

Webmasters can help by warning about the dangers of trading exotic species, and by pointing out the various regulations governing the movement of biological material. Without greater precautions, the liberties of the virtual world could easily take their toll on the much more precious real one. (*Biodiversity and Conservation*)

—Nick Atkinson

Maremma, a Tuscan breed of cattle





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Great Lake Bake

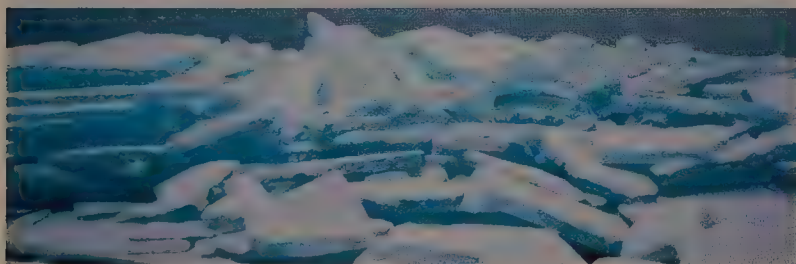
With so much evidence that global warming is real, it's no surprise to learn that summer temperatures on Lake Superior have been rising for twenty-seven years. More puzzling, however, is that the water temperature is increasing faster than the air temperature around the lake.

Two limnologists, Jay A. Austin and Steven M. Colman, both of the University of Minnesota Duluth, analyzed data gathered since 1980 from surface buoys and weather stations in and around the Great Lakes. They report that the average summertime air temperature around Lake Superior rose 2.7 degrees between 1980 and 2005. Yet the average water temperature increased almost double that amount, about five degrees. Preliminary analyses show similar trends for lakes Michigan and

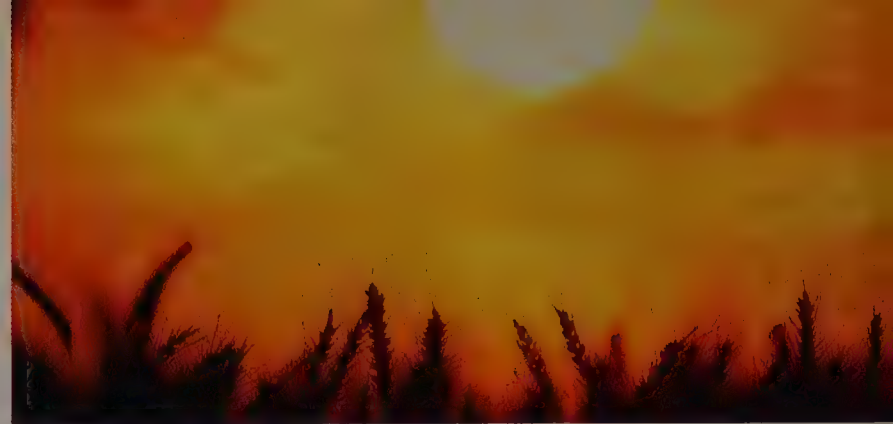
Huron; Lake Erie is warming, too, though more slowly.

Why the steep rise in summer water temperatures? Austin and Colman discovered that Lake Superior's winter ice cover has been shrinking by an average of 0.4 percent a year. Water is warmed by contact with the overlying air and by the Sun's radiation. Light-colored ice reflects more sunlight than dark-colored water. Less ice in the winter leads to an earlier thaw in the spring, and therefore a longer sunning season.

At the current rate of change, Lake Superior will be ice-free most years in about three decades. Big lakes can have big regional weather effects and sustain important fisheries, so the rapid warming of three Great Lakes should make North Americans sit up and take note. (*Geophysical Research Letters*) —S.R.



Icing on the Lake



Cereal Killer

The consequences of global warming loom far in the future, or so most people think. But farmers are already feeling the heat—in fact, they've been losing crops to rising temperatures for more than twenty-five years.

Many factors affect crop yields: pollinators, seed strains, and farm technology, to name a few. To tease out the effect of temperature, two ecologists in California, David B. Lobell of Lawrence Livermore National Laboratory in Livermore and Christopher B. Field of the Carnegie Institution in Stanford, designed a statistical model. The model integrates worldwide temperature, rainfall, and yield data from 1961 through 2002 for the world's six most widely planted crops—barley, corn, rice, sorghum, soybeans, and wheat.

In those four decades total crop yields nearly doubled. Yet Lobell and Field determined that, as global temperatures began to rise

in the early 1980s, the extra heat slowed the growth. By 2002, about 40 million tons of barley, corn, and wheat—worth nearly \$5 billion and constituting 2 to 3 percent of the crop—were being lost each year. Since then, temperatures and crop prices have only increased, so the value of the missing crops should continue mounting.

One of the primary causes of global warming, however, has just the opposite effect on cereals: rising levels of carbon dioxide (CO₂) increase crop yields. Lobell and Field estimate that the yield gains from higher CO₂ levels were roughly equal to the losses from heat. So far, so good—but as CO₂ levels climb, the yield gains are predicted to decelerate, while the losses should speed up and overtake them. Meanwhile, the population keeps adding mouths that farmers and agronomists must figure out how to feed.

(*Environmental Research Letters*)

—Rebecca Kessler

Let the Sunshine In (Or Maybe Not)

Haze—made up of dust, soot, and other airborne aerosol particles—seems to have been on a steady, worldwide decline during the past decade and a half, according to new research. That's cause for a round of pats on the back, since it could signal a drop in pollution. But some nail-biting might also be in order. Haze reflects incoming sunlight back to space, so less haze permits more sunlight to reach Earth's surface, enhancing global warming.

To quantify the trend, Michael I. Mishchenko, a physicist at the NASA

Goddard Institute for Space Studies in New York City, and his colleagues analyzed data from weather satellites on the amount of sunlight reflected by haze over the world's oceans. The data indicate that since 1991, the opacity of the haze has declined by as much as 20 percent. That's not nearly enough to explain global warming as a whole—but it could have contributed to the greater-than-expected rise in temperatures of the past decade.

The results also mesh nicely with observations that the amount of sunlight

reaching the Earth's surface has jumped noticeably, beginning in 1990. Whether "global brightening," as the phenomenon is called, is a direct consequence of pollution-control measures, or merely reflects changes in naturally occurring airborne particles, remains uncertain. But NASA's Glory mission, scheduled to launch a new satellite in December 2008, could help clarify the matter. The new satellite will carry a sensor that can distinguish between natural aerosols and pollution.

(*Science*)

—S.R.

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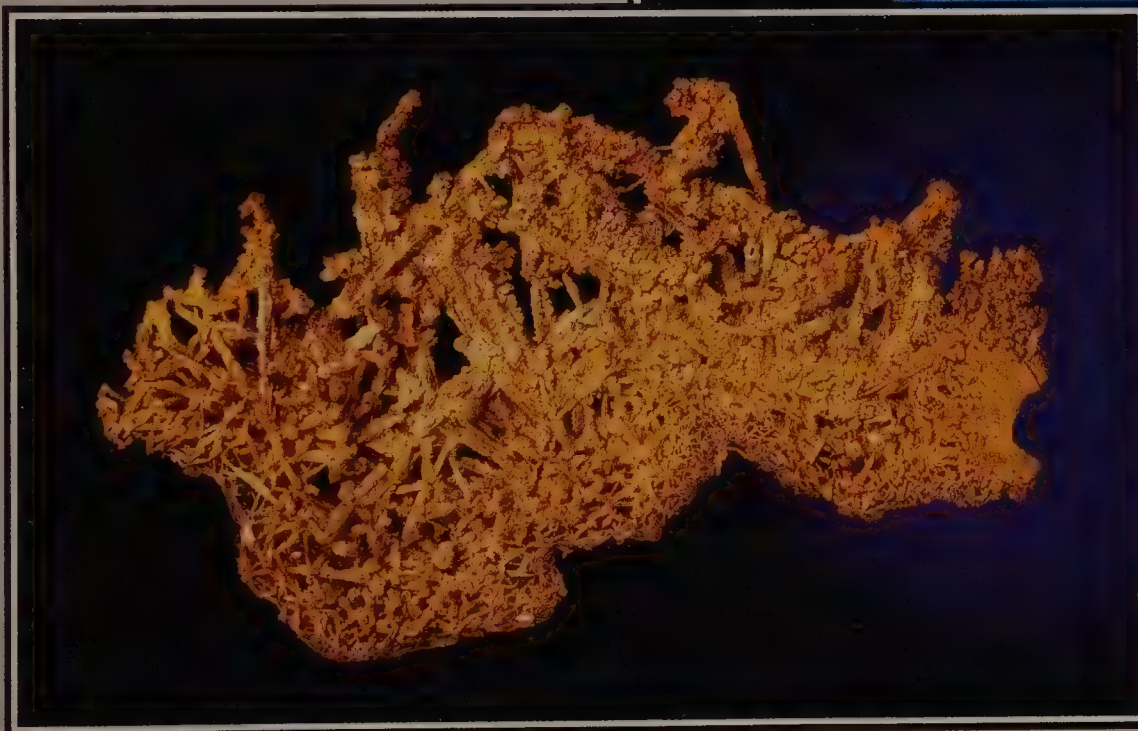
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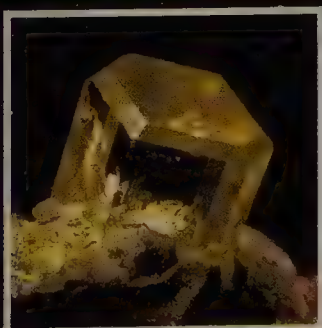


Aquamarine
Shigar Valley,
Pakistan; 7 inches



Gold, 4.2 inches
Wire Patch Mine
Breckenridge, Colorado
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Photographs by Jeffrey Scovil
Arkenstone specimens



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Bones from the Tar Pits

La Brea continues to bubble over with new clues about life that flourished 40,000 years ago, where Los Angeles is today.

By John M. Harris

We have dredged and scraped, on hands and knees, to a depth of fourteen feet, where the air is redolent with sulfurous hydrocarbons. Our excitement mounts as we expose the skull of a saber-toothed cat, entombed in the asphalt. This site, Pit 91, lies within one of the richest pockets of Ice Age fossils in the world, and



those of us working the pit collect thousands of bones and hundreds of gallons of surrounding material every summer. Finding a saber-tooth here is common, yet every skull continues to be special. Will this one have its canines? Its lower jaw?

The skull turns out to be nearly complete. One summer as long ago

as 40,000 years, the great cat might have ventured onto uncertain ground to feed on an easy target, a bison perhaps, mired in the sticky asphalt, or "tar." The temptation would be the cat's last. When the saber-tooth attacked, its fate—along with the bison's—was sealed. It and literally thousands of other animals have become trapped at a unique spot that paleontologists now comb for remnants of ancient life.

With the discovery of the saber-tooth our dedicated band of tar-stained volunteers takes a brief pause, but soon they are back at work, painstakingly continuing the excavation of Pit 91. The justly famous La Brea tar pits lie just seven miles west of downtown Los Angeles, in what is known as Hancock Park, where Pit 91 is the last active

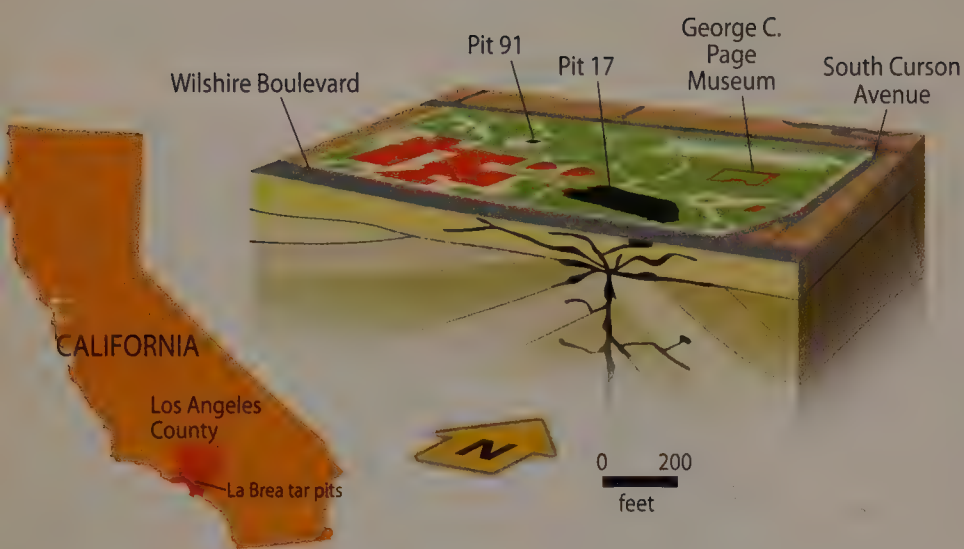
excavation [see map on page 20]. The volunteers work under the guidance of Christopher A. Shaw, the collections manager for the George C. Page Museum, which was built by the Natural History Museum of Los Angeles County in 1977 to house fossils from the tar pits. Shaw keeps the excavators following a rigorous procedure not unlike the one initiated here by paleontologists in the early 1900s. (Boiling kerosene, though, no longer serves to clean the sticky bones—nor does it accidentally catch fire and singe the eyebrows of workers.) Shaw's volunteers clear square grids three feet on a side and dig down through the layers six inches at a time, all the while coping with the thick asphalt bubbling up around the bones.

In spite of those challenges, the excavation pours out the remains of fossils from the late Pleistocene epoch, between 27,000 and 40,000 years ago, some of which may be completely new to science. Since the current excavation began in 1969, more than 320 species have been added to the 270 or so that were first collected here ninety years ago. Together they provide a detailed picture of ancient life in the Los Angeles Basin, from giant mammals down to water fleas.

R real tar, technically, is a product distilled from wood, coal, or peat, whereas the sticky black "tar" responsible for the rich accumulation of fossils is natural asphalt made up mostly of crude petroleum. It oozes up through natural plumbing in the Earth's crust from the Salt Lake Oil Field, about 1,000 feet below the surface of Hancock Park. More petroleum has collected even farther

Early excavations at the La Brea tar pits of central Los Angeles during the period 1913–1915 (above left) unearthed roughly a million bones from nearly a hundred sites. All the fossils were housed in the old "bone room" (right) at the Natural History Museum of Los Angeles County, before being transferred to the George C. Page Museum in 1977.





down—as deep as 10,000 feet underground—in 5-million-year-old rock, which helps feed the current asphalt seeps. The pressures at such depths have squeezed crude oil, natural asphalt, and methane gas to the surface for at least the past 50,000 years. Similar sites have been discovered in Asia, the Middle East, South America, and elsewhere. One exciting asphalt seep in Venezuela has recently been coughing up ancient armadillo fossils.

In California, people collected the asphalt from the tar pits long before its fossil content was discovered. Native Americans began using it in pre-historic times as a caulk for baskets and canoes. Early settlers in Los Angeles used it as a fuel and as waterproofing for their roofs. In 1828, when southern California was still part of Mexico, the Mexican government included the current La Brea pits as part of a land grant known as Rancho La Brea (Spanish for “the tar ranch”), which stipulated that the landowner must permit Angelinos to retrieve as much tar as they needed for personal use. By the late nineteenth century, asphalt from La Brea fetched twenty dollars a ton after it was refined for various purposes, including road building.

Bones recovered in those early collections were dismissed as the remains of domestic animals. It was not until 1875 that the geologist William Denton visited the tar pits and identified the canine tooth of a saber-toothed cat. Denton reported his find, but the rest of the scientific community took little

notice. No one bothered with any large-scale recovery of the fossils until after 1901, when William W. Orcutt, a geologist who was investigating oil resources in the vicinity, noted that the bones in the asphalt seeps belonged to many extinct species.

Suddenly the tar pits became all the rage, as amateurs and institutions competed for the fossil treasures. Excavation peaked at Rancho La Brea between 1905 and 1915, when literally millions of bones were taken out of the ground. In 1913, the landowner, George Alan Hancock, finally acted on his fears that the fossils would be taken from the community and scattered widely; he granted exclusive rights to excavate the fossil resources to Los Angeles County’s fledgling Natural History Museum—but only for two years.

The museum took full advantage of its brief time window. Between 1913 and 1915, museum crews intensively explored the twenty-three acres of the area that would become Hancock Park, making nearly a hundred excavations and collecting roughly a million bones. Hancock later donated that part of his property to the county, with instructions that the tar pits be preserved and appropriately displayed.

The spectacular array of fossils from the 1913–15 excavations were subsequently housed in the basement of the Natural History Museum. They included carnivorous saber-toothed cats, dire wolves, lions, and short-faced bears, as well as herbivorous camels, ground sloths, mammoths, and mastodons. In all, the species count from the excavations in the early 1900s included 133 birds, 63 insects, 43 mammals, and 29 plants, plus a handful of amphibian, mollusk, reptile, and water flea species.

Thick, sticky asphalt seeping to the surface from petroleum reservoirs thousands of feet underground has trapped animals for tens of thousands of years, as portrayed in the schematic diagram. In summer, when the asphalt liquefied, animals such as the ground sloth (left panel) became stuck and then, often, were killed by carnivores. In winter, the asphalt hardened and sediment mixed with it to cover the seep (center panel). For thousands of years the matrix of asphalt and sediment has accumulated, along with the remains of trapped animals, plants, and seeds, creating large, inverted cones underground, chock full of fossils (right panel).



What makes the tar such an effective and deadly animal trap? In the warm summer months the asphalt reaching the surface becomes viscous and sticky, and so it quickly acquires a deceptive surface covering of dust and leaves. Cows and horses have been observed in modern times wandering across oil seeps, where an inch or so of sticky asphalt is all it takes to totally immobilize them. Similarly, Pleistocene herbivores inadvertently stepping into the edges of the La Brea seeps would have found themselves held as fast as flies on flypaper—vulnerable to starvation, dehydration, and predatory attacks.

As cool winter temperatures returned, the asphalt would resolidify, sealing in the summer's bones. Winter winds and rain would further cover the surfaces of the seeps with sediment washed down from the nearby Santa Monica Mountains. Then, once temperatures warmed up in the spring, the seepage would start again, and the trap would reset. For a few thousand years, masses of tangled bones would accumulate in conical pits on the rising coastal plain, until the existing vents became blocked [see illustration below]. Most of those accumulated bones, paleontologists found, were carnivores; in fact, they outnumbered herbivores by almost nine to one. The bird species, too, were primarily birds of prey. Such an abundance of carnivores at La Brea led to the entrapment hypothesis: that mired animals served as bait for predators and scavengers.

In the half century that followed the initial description of the Rancho La Brea fossils, it became apparent that crucial information was missing. The museum excavators had concentrated on the trophy specimens—the lions, mammoths, and saber-toothed cats—and had largely ignored smaller fos-

sils such as rodents, seeds, and snails. Paleontologists now recognize that the smaller fossils often provide the best evidence about the habitats and environments in which the fossils accumulated. Larger creatures may have wandered for miles during their lives, whereas the small mammals and insects probably never strayed more than a few hundred feet from where they were trapped.

So in 1969 the Natural History Museum of Los Angeles County began another excavation, focusing on Pit 91, which had been discovered in 1915. County museum staff had left the mass of bones in place, hoping for a future exhibit that would show park visitors how the fossils were found in the ground. Fortunately for science, the bone mass remained undisturbed in the ensuing years. And on Friday, June 13, 1969—"Asphalt Friday" of Page Museum lore—the excavation of Pit 91 began.

The new excavation has added 131 plant species, 88 insect species, 63 mollusk species, and 18 small-mammal species to the menagerie of Rancho La Brea. Moreover, the masses of bones from Pit 91, cleaned and catalogued, helped to prepare a test for the entrapment hypothesis. I took part in that project with Lillian Spencer, an anthropologist at Arizona State University in Tempe; Blaire van Valkenburgh, a paleobiologist at the University of California, Los Angeles (UCLA); and a team of UCLA students. Together we studied 18,000 bones and found, first of all, that the great majority of them showed little or no weathering. Once the bones were mired in asphalt, they were rapidly buried by sediment, debris, and more asphalt—rather than being exposed or carried for any distance.

What about other markings on the bones? If the asphalt seeps acted as carnivore traps, with mired



animals as bait, one might expect to find tooth marks, for instance. Yet of the 18,000 bones, only 2 percent had been scored, notched, or punctured by carnivores, and 76 percent of the adult bones were complete. Nevertheless, our study also noted that many bones from ground sloths, ruminants, and deer were so fragmentary they could not be properly identified. Those bone fragments had probably been scavenged and crushed by predators near the asphalt seeps. The unmarred bones were probably from parts of the carcasses too mired in asphalt for carnivores to disturb.

The skeletal proportions of the trapped animals provide further, telling evidence of scavenger activity. Carnivores at kill sites often remove a limb from a carcass and carry it to a safer place for feeding. A tally of each of the seven most common species at Pit 91 showed that for every skull in the sample there was only one forelimb and one hind limb. The missing limbs provide strong circumstantial evidence that mired animals were ravaged by carnivores. The skeletal remains also show



*Cleaned skull of a
saber-toothed cat*

that not all species were equally attractive to scavengers. For horses, more than 75 percent of the limb bones were represented, whereas among bison, more than half the limb bones were missing. The bison bones also tended to be less complete than those of the horses. Spencer, van Valkenburgh, and I think those data show that carnivores preferred bison limbs, probably because of their greater fat content.

Our interpretation recently gained support from work I undertook with Joan B. Coltrain, an archaeologist at the University of Utah in Salt Lake City. Features of an animal's diet and local environment can be inferred from the proportions

of stable isotopes in its remains. For example, the ratio of nitrogen-15 to nitrogen-14 changes from species to species when moving up the food chain, providing a clue as to who is feeding on whom. By analyzing the nitrogen-isotope ratios in bones from Rancho La Brea, we found that the coyotes were omnivorous; that the dire wolves and lions were feeding on horses, ground sloths, and ruminants (but not on mastodons); and that the saber-toothed cats preferred bison and camels.

The asphalt continuously seeping into Pit 91 has been a constant problem for the excavators, but the muck, even without bones, has opened up an unexpected line of research. A recent study by David E. Crowley and Jong-Shik Kim, both microbiologists at the University of California, Riverside,

revealed that hundreds of species of bacteria and archaea also thrive in the asphalt seeps. One key part of the microorganisms' adaptation to life in the asphalt is that they "eat" petroleum: they grow by breaking down petroleum hydrocarbons, which they incorporate into their cells.

The discovery of such microfauna has enormous potential for biotechnology. To take just a few examples, understanding their biochemical pathways could lead to new medicines, polymers, and petroleum-based biodegradable plastics. If some of the microorganisms can be isolated from the asphalt and grown in the laboratory, they may be effective in treating oil wastes and contaminated soils.

At the present work rate, the excavation of Pit 91 could take another ten to fifteen years to complete. In that time, continuing research on the microorganisms could lead to an efficient way to clean the backlog of bones at La Brea—not to mention fossils from other asphalt seeps around the world. If that comes to pass, a lot of storage containers at La Brea undoubtedly hold the bones of new species—as well as trusty saber-tooth skulls—that will finally get the cleaning they deserve. □



Pit 91 continues to be excavated every summer with the help of volunteers. Bones larger than a half inch long are removed for cleaning; the surrounding asphalt is saved in the hopes of future processing.

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Survival of the Rarest

The forests of southern Bahia, Brazil, threatened by development, shelter numerous rare plants, which botanists are racing to document before they disappear.

By Wm. Wayt Thomas

Come on, it's right up here, at the edge of the forest," Jomar shouted as he bounded through the sun-dappled plantation. *Theobroma cacao* trees, the source of cocoa and chocolate, grew all around us, partly shaded by a high overstory of native rainforest trees. When we reached the far edge of the cacao plantation, or *cabruca*, the parklike ground gave way to untended tropical forest, a dense riot of herbs, shrubs, and vines, all crowding upward and outward. Jomar walked along the forest's edge for a while, then bent down, pulled some shrubs aside, and motioned me over.

The two of us squatted to examine what Jomar had sought out: one of the world's rarest plants. *Anomochloa marantoidea* is a low-growing, clumped

grass with wide, pointed, oval leaf blades about six inches long. Now known to be the most primitive species in the grass family, *A. marantoidea* holds a special fascination for botanists who study the evolutionary history of grasses. The species, the only one in the genus *Anomochloa*, was first described scientifically in 1851. But the description was based on plants grown in Paris from seeds of uncertain provenance. They were thought to be from the southern part of the Brazilian state of Bahia, where Jomar and I now crouched.

In 1976 a botanist from the Smithsonian Institution in Washington, D.C., Cleofé E. Calderón, went to Bahia with the goal of rediscovering *Anomochloa*. She had tried, but failed, to do so on an earlier expedition, despite the assistance of a gifted local plant collector, Talmon S. dos Santos, of the Brazilian government's Cocoa Research Center (known as CEPEC, for its name in Brazilian Portuguese) in Ilhéus. Calderón and dos Santos—a



Dense forest in southern Bahia (left) typifies the region's botanical diversity, concealing rare and potentially intriguing plant species. As the map shows (above), only about 8 percent of the region's original forest remains.

former logger with a fifth-grade education—spent days fruitlessly searching the forests of southern Bahia. Finally, on a foray during which the pair had split up to cover more ground, dos Santos found the species that had gone missing 125 years earlier.

It was a population of about ninety *Anomochloa* plants, the same one Jomar and I now examined. We found the population diminished to just thirty plants, but otherwise healthy, ignored, and for the time being safe. Only one other population—located near the first—has been found in the years since the species' rediscovery.

Anomochloa is just one of many rare plants inhabiting southern Bahia, where I have been studying plant diversity for more than fifteen years. I work closely with Jomar—full name, Jomar G. Jardim—a doctoral candidate at the State University of Feira de Santana; André M. Amorim, a botanist at the State University of Santa Cruz in Ilhéus; dos Santos; and others at CEPEC. We share a particular interest in rare plants, not only because they are the species most at risk of extinction, but also because their ecology, chemistry, and potential uses are often all but unknown. Knowledge of rare plants in economically important families, such as *Anomochloa* in the grasses, could guide botanists in improving more common, marketable species. Some rare plants are limited to a certain soil type or a certain microclimate, and so they are useful “indicator species” for identifying and understanding those unique ecosystems. Finally, rare species with narrow ranges can help conservationists determine which areas merit the highest priority in the efforts to conserve biodiversity.

But finding and documenting rare plants is no small challenge, as you might imagine, in the diverse forests of a region such as southern Bahia. As one of the world's biodiversity “hot spots,” the region is so complex that bringing rare species to light is often a matter of chance encounters deep in the jungle. A survey is also complicated by the uncertain future of the forests themselves.

Southern Bahia is an area about the size of Connecticut and New Jersey put together. Within the region, rainfall, topography, and geology all vary, giving rise to a patchwork of distinct forest types and an extremely rich flora. A two-and-a-half-acre survey might reveal more than 250



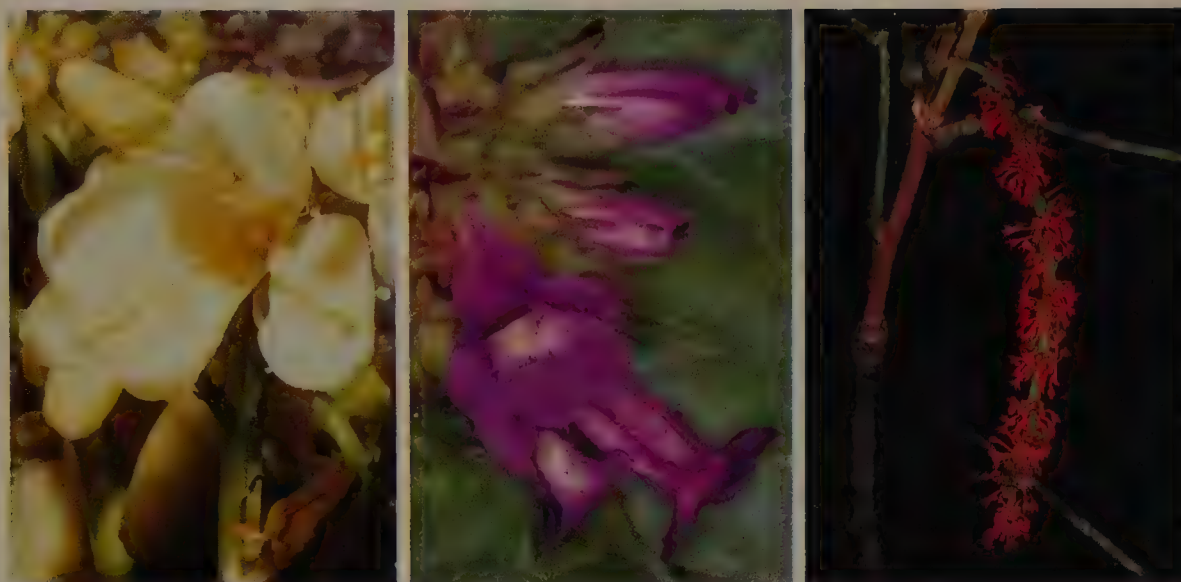
Plant specimens from a southern Bahia forest come back for identification and analysis in plastic bags carried by the author (right), André M. Amorim (center), and two of their colleagues.

species of trees whose trunks are more than four inches across. By comparison, all the native trees in temperate eastern North America belong to just 230 species. More than a quarter of the plant species in southern Bahia are endemic to the region—an unusually high number—as are numerous mammals, birds, and other animals.

The forest in southern Bahia is part of Brazil's Atlantic coastal forest, a strip that in pre-Columbian times reached 200 miles wide and stretched more than 1,500 miles along Brazil's eastern coast [see map on opposite page]. Five centuries of deforestation for agriculture and development have reduced the intact forest canopy to a mere 8 percent of its original acreage—a trend that continues to this day.

Precisely because of their scarcity, rare plants are the most vulnerable to deforestation. Many, such as *Anomochloa*, are known from startlingly few locales. In 1981, for instance, dos Santos and a colleague discovered an unusual tree with yellow flowers that they had never seen before in a cocoa plantation on CEPEC's grounds. In 1998 a botanist assigned it to a new genus of the orange family (the Rutaceae) comprising a single species, *Andreodoxa flava* [see leftmost photograph on next page].

In spite of its conspicuous yellow flowers and years of searching by botanists, the genus *Andreodoxa* is still known only from that single individual, pro-



Andreadoxa flava (left) is known only from a single tree. *Gloxinia macrophylla* (center) occurs in just one known population; its habitat is poorly explored, however, and additional surveys could reveal more plants. After first discovering *Picramnia coccinea* (right), the author noticed the species in familiar, well-studied forests, whose lush vegetation had previously hidden it.

tected between two boulders in a cabruca. Since *Anomochloa* and *Andreadoxa* are known only from cabucas, they might be restricted to the same moist, fertile soils that cacao trees prefer. If so, they were probably more common before cocoa became widely cultivated than they are today. Perhaps other rare species share a similar history.

Fortunately, in the cases of both *Anomochloa* and *Andreadoxa*, the right person passed by a rare species at the right time and noticed it. But how many other populations of those two species have simply never been noticed? And how many other species have been overlooked entirely or have even disappeared as a result of deforestation before biologists could describe them?

Even if other populations remain to be discovered, it is clear that *Anomochloa* and *Andreadoxa* are, at best, uncommon plants. Other species are hard to find for different reasons. Some are common in certain areas, but restricted to a small range. Others are rare in southern Bahia but more common elsewhere. Still others have been discovered in areas that remain poorly known; those species might turn out to be more common once such areas are better surveyed.

That last scenario is the case for a relative of the African violet, *Gloxinia macrophylla*—a low-growing, fuzzy-leafed plant with bright purple flowers almost two inches long [see middle photograph above]. My colleagues and I were amazed to encounter a population of *G. macrophylla* while exploring a dry forest, one of southern Bahia's least studied and most threatened habitats. The species had been collected in the same

area for the first and only other time in 1817. *G. macrophylla* was described scientifically in 1823 and, despite its showy flowers, was never again collected until we happened upon it. Is it as rare as *Anomochloa*? We can't yet tell.

Actually, the extraordinary diversity of the Bahian forests has the somewhat paradoxical consequence that even the most common species are scarce. That makes the inconspicuous or rare ones difficult to find indeed. The plants come in so many different shapes, sizes, and varieties—and so few of them display distinguishing flowers or fruits at any one time—that noticing something new is difficult.

Once, when collecting in a forest fragment inside the city limits of Ilhéus, I came upon a six-foot-tall tree with spikes of red flowers [see rightmost photograph above]. I knew right away that it was a species of *Picramnia*, but I had never seen anything like it before. My colleagues and I looked around and found a few more, all lacking flowers or fruits. Curiously, when we returned to two nearby forests where we had repeatedly collected, *Picramnia* was there, too, no longer invisible amidst the background vegetation. It wasn't common or easy to spot, but it certainly was present. It turned out to be a species new to science, which I later described as *Picramnia coccinea*.

Quantitative studies, in which botanists collect and identify every woody plant in a plot, are a good way to unmask such invisibility. One such study in southern Bahia led to the discovery of a dozen tree species, all new to science. The new species comprised more than 10 percent of the tree flora in their home forest—yet because their flowers and fruits are hidden in the canopy, they had never before been noticed.

The history of southern Bahia's forests largely dictates the rarity or abundance of the region's plant species. Unlike the Amazonian forests farther inland, the Atlantic coastal forest has been strongly affected by European colonization for more than half a millennium. On April 22, 1500, the Portuguese explorer Pedro Cabral and his crew were the first Europeans to set foot on the land now called Brazil. The Portuguese quickly settled, inexorably displacing the indigenous Tupi. The first colonists

in southern Bahia grew sugarcane and cotton and harvested pernambuco trees from the forest. Pernambuco (*Caesalpinia echinata*), or brazilwood, is endemic to the Atlantic coastal forest. Its beautiful deep-red wood yields a red dye that became an immediate commercial success for the Portuguese and led to the decimation of the species.

In the 1740s cacao, native to the Amazon Basin, was introduced for cultivation in the forests of southern Bahia. It wasn't until the second decade of the 1900s, however, that its cultivation—predominantly in cabruças—became widespread. By the late 1970s cabruças covered a million acres in southern Bahia, and dry cocoa beans fetched more than \$3,700 a ton.

In the cabruca system only the forest understory is cleared, and cacao trees are planted in the shade of the original canopy [see “The Chocolate Tree,” by Russell Greenberg and Robert A. Rice, July/August 2003]. Cabruças thus preserve some of the original diversity of trees and epiphytes in the forest, and they provide some habitat and nourishment for birds and primates.

But the diversity preserved in the cabruças suffered a severe setback following the crash of the region's cocoa-driven economy in the late 1980s and 1990s. Increased cocoa production throughout the world dropped prices to around \$1,200 a ton by 1999. And as the price was bottoming out, a disease fungus, *Crinipellis perniciosa*, swept through the Bahia plantations, reducing Brazil's annual cocoa output from 380,000 tons in the late 1980s to 90,000 tons in the late 1990s. Brazil, the world's second-largest exporter in the 1980s, had to import cocoa.

When prices and production fell, the income from a typical plantation dropped to a tenth of its former level. Families who tended the cacao abandoned the farms for the cities. Many landowners could no longer maintain their cabruças, so they felled the shade trees for timber and cleared the land for pasture or coffee plantations. Half the forest acres that had been semipreserved in cabruças were permanently cleared.

Today, most of southern Bahia's scant remaining forest is under development pressure of one kind or another. Moist, fertile soils make the hilly region near Ilhéus ideal for growing cacao; most of the natural forest there has already been converted to cabruças. Woodlands and sandy savannas along the coast, called *restingas*, are severely threatened by beachfront development. The hot, humid, low-lying forests of the southern coastal plain, called *tabuleiro*

forests, are ideal for pastures, for papayas and other crops, or for large-scale plantations of eucalyptus, grown for paper. The drier inland forests, the most threatened, have soils that are excellent for pastures. It comes as no surprise, then, that most of the large forest fragments that have remained intact possess poor soils that are relatively undesirable for agricultural development.

As Jomar and I studied the population of *Anomochloa*, counting the individual plants and their inflorescences, I was struck by their precarious future, and that of the forest ecosystem around them. Will the family that owns the forest maintain it as is, or will they clear its understory to plant more cacao? Does the *Anomochloa* population (and others that may still lie undiscovered) have the genetic diversity to perpetuate itself? And what about *Andreodoxa*? Is it one of the “living dead,” a single individual



Crop of green cassava plants grow among the debris where trees once stood. Most of the scant forest remaining in southern Bahia is under pressure for agricultural or housing development.

doomed to extinction? What of the other endemics to southern Bahia—plants and animals alike?

I remain hopeful that preservation of key areas in a variety of forest ecosystems can preserve enough species—and enough genetic variability within each species—to ensure their long-term survival. That hope drives my work: improving the understanding of Bahian forests so that the crucial decisions about conservation can be made as wisely as possible. □

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Darwin in Court

Eighteen months after the “monkey trial” in Dover, Pennsylvania, a bumper crop of books puts the battle in perspective and asks, What’s next?

By Richard Milner

*I am inclined to believe
The story of Adam and Eve.
There’s no chimpanzee
In my pedigree*

And you can’t make a monkey of me.

—From the song “You Can’t Make a Monkey Out of Me,” popular during the Scopes-trial era;
©Billy Rose and Clarence Gaskill, 1925

Every few years in America (and nowhere else) God tells someone to haul Charles Darwin and evolutionary biology into court. No other scientific theory—not atomic theory, not string theory, not the big bang—has ever been put on trial in a court of law. That may be because “Darwin matters,” to borrow a phrase from Michael Shermer, a historian of science and self-labeled “former fundamentalist.” Shermer’s essential little book, *Why Darwin Matters*, shows how the revolutionary Darwinian time bomb is still ticking. Subtitled *The Case Against Intelligent Design*, the book refutes creationism’s latest incarnation and chronicles the recent brouhaha over high school textbooks in Dover, a small town in rural Pennsylvania.

Three years ago, members of the Dover school board decided to require teachers or administrators to read a formal disclaimer in ninth-grade biology class, urging students to be skeptical of Darwin’s “theory” of evolution and to consider intelligent design (ID) as an alternative explanation for the origin of life. They also sought to introduce an auxiliary textbook that promotes ID, *Of Pandas and People: The Central Question of Biological Origins*, by Percival Davis and Dean H. Kenyon. Tammy Kitzmiller, a working mother with two daughters in the high school, along with ten other parents, sued the board for violating their constitutional rights under the First Amendment’s Establishment Clause. *Kitzmiller v. Dover Area School District* was

the first time anyone had challenged a public school district in the federal courts about the teaching of ID, which the parents argued was not a scientific theory at all.

Board members protested that their agenda was not about religion, but rather about teaching an important new scientific idea. A new idea? Hardly. In 1831, when Charles Darwin, then a young theology student, set sail aboard HMS *Beagle*, he believed in design by a Creator. He also accepted the church-approved doctrine that the Earth’s species had been created instantaneously and in their present form. Like the seventeenth-century theologian William Paley, Darwin thought that such marvels of natural engineering as the human eye and the eagle’s wing were “evidences” of the Creator’s handiwork. Paley’s famous watchmaker analogy—if you find an intricate timepiece, you must conclude it had a maker—was a well-worn form of argument for the existence of God, traceable back to Thomas Aquinas and beyond.

In John Brockman’s anthology *Intelligent Thought: Science Versus the Intelligent Design Movement*, the historian of science Frank Sulloway of the University of California, Berkeley, has concisely traced Darwin’s path in rejecting those ideas. During the voyage of the *Beagle*, Darwin began to see that animals and plants had been patched together and modified throughout a period of organic evolution. Evolutionary history, with all its quirky and sometimes inefficient pathways, is embedded in our bones.





Artist's digital collage portrays a classroom dominated by icons of evolution. The teacher gestures toward Pennsylvania, site of the landmark case *Kitzmiller v. Dover Area School District*.

Does nature ever produce a downright *unintelligent* design? That question is addressed (unforgettably, but alas, unsatisfactorily) in the lighthearted documentary *Flock of Dodos*, made by Randy Olson, a marine-biologist-turned-filmmaker. In Olson's film, James Hanken, the director of Harvard's Museum of Comparative Zoology, gives his Award for Most Unintelligent Design to—of all animals—the rabbit. “It’s a truly disgusting design,” he adds.

When rabbits chew and swallow their veggies, Hanken explains in the film, they shunt the food past both large and small intestines to a special fermentation pouch, known as the cecum, from which they expel marble-size pellets called cecotropes. Then, at night, your pet bunny eats its own droppings. This time, however, they are processed in the intestines, where the half-digested food is absorbed,

and the resulting waste discharged as true feces. Who knew? Olson's night-vision camera shows a rabbit filmed in the dark, and, sure enough, you can actually see what's up, doc. “For every example of intelligent design in nature,” says Hanken, “I can cite you ten others of *unintelligent* design.”

But that's just one way of looking at it. The rabbit works well enough to have survived, after all, so it must be a successful design—no matter what we might think about the “intelligence” of a design that requires an animal to eat its own excreta. Indeed, it is peculiar for a biologist to maintain that some living things are less intelligently designed than others. If all biological systems arose from natural, mechanistic processes, they're *all* unintelligently designed.

Although the phrase “intelligent design” does invite “unintelligent design” as its opposite, the op-

erative word is "design." Creationists believe that you can't get something as complicated and finely tuned as a rabbit through unplanned, intermediate steps. The greater the intricacies, they insist, the higher the intellect must have been to create it. That biologists think that they could improve on the design of the rabbit is ultimately no answer to the creationists' argument, particularly if the improvements merely reflect human prejudices about what is an optimal or beautiful design.



But if biologists can't shed their human constraints, neither can the advocates of ID. Throughout the film, they keep showing Olson pictures of Mount Rushmore, insisting that any fool can see that the granite presidential portraits must have been designed, rather than the result of natural forces shaping the mountain. "Yes," Olson keeps adding, "by a *human* designer."

Olson and his film crew crisscrossed the country, interviewing creationists and ID advocates, as well as evolutionists. Some of the opponents of evolution turn out to be disarmingly likable, whereas some of the scientists can be arrogant and off-putting. During a poker game among Ivy League biologists, when the conversation turns to ID, the pros sound as smug and condescending as any entrenched priesthood. In so doing, they have thrown away a winning hand.

Both sides, in the filmmaker's view, are silly, vulnerable dodos. Like those extinct birds, creationists cannot adapt; they're unaware that their under-

It is peculiar for a biologist to maintain that the world is more intelligently designed than others. If all biological systems are designed, they're all unintelligently designed.

standing of nature was decisively displaced more than a century ago. But the evolutionary biologists are equally behind the times. They seem blind to the information revolution, in which public relations gurus and spin doctors promote disguised religious agendas with spectacular success.

Matthew Chapman is no dodo. A Hollywood screenwriter, he covers the Dover trial with an ear for idiosyncratic language and a dramatist's eye for the nuances of character. His reportage in *40 Days and 40 Nights* is a tour de force, hilarious without sacrificing seriousness of purpose. Chapman, by the way, is a great-great-grandson of Charles Darwin: his is a personal quest for the meaning and impact of his family legacy.

Chapman squelches any inclination he might have had to imitate H.L. Mencken, the acerbic American journalist who, during the 1925 Scopes trial, sneered that the creationists were hicks and hillbillies, and who coined the enduring term "Bible Belt." Rather, Chapman argues, to dismiss militant religionists as harmless and trivial is to invite being blindsided. Most scientists, he writes, simply cannot imagine that religious fundamentalists "might eventually, through sheer force of will and faith engendered by bitterness or fear, emerge victorious."

Works Discussed

Intelligent Thought: Science versus the Intelligent Design Movement
edited by John Brockman
Vintage, \$14.00

40 Days and 40 Nights: Darwin, Intelligent Design, God, OxyContin®, and Other Oddities on Trial in Pennsylvania
by Matthew Chapman
HarperCollins, \$25.95

Creationism's Trojan Horse: The Wedge of Intelligent Design
by Barbara Forrest and Paul R. Gross
Oxford University Press, \$19.95

Monkey Girl: Evolution, Education, Religion, and the Battle for America's Soul
by Edward Humes
HarperCollins, \$25.95

Flock of Dodos: The Evolution—Intelligent Design Circus
(comedic-documentary film: 85 minutes)
Written and directed by Randy Olson
Prairie Starfish Productions, home video to be distributed by New Video, August 28, 2007, \$26.95

Not in Our Classrooms: Why Intelligent Design Is Wrong for Our Schools
Edited by Eugenie C. Scott and Glenn Branch
Beacon Press, \$14.00

Why Darwin Matters: The Case Against Intelligent Design
By Michael Shermer
Times Books, \$22.00

The Battle Over the Meaning of Everything: Evolution, Intelligent Design, and a School Board in Dover, PA
by Gordy Slack
Jossey-Bass, \$24.95

Some living things are less intelligently
rose from natural, mechanistic processes,

Edward Humes, a nonfiction writer and Pulitzer Prize-winning journalist, and Gordy Slack, a science journalist, also covered the Dover trial, apparently often bumping into Chapman and each other. They, too, have produced excellent, if inevitably overlapping, accounts. Humes gives the most detailed coverage of the testimony and cross-examination of witnesses. His account of the cross-examination of Michael J. Behe, an amiable biochemist from Lehigh University and the only major proponent of ID to take the stand, is particularly compelling. Behe is well known for his argument that a mousetrap exemplifies “irreducible complexity,” because it could not work if even one element were missing from its design. But the plaintiffs’ lawyers mousetrapped Behe into contradicting his own ideas.

Judge John E. Jones III, an appointee of President George W. Bush, presided over the case. Slack describes Jones as having “something of the conservative 1950s father figure about him.” A lifelong Republican, Jones has flatly stated that he is not a judicial activist. Yet the judgment he eventually reached outraged some of his fellow conservatives.

Among the various scientists, theologians, atheists, deists, and politicians who appeared before Judge Jones (it was a bench trial, without a jury), one was Eugenie C. Scott, executive director of the National Center for Science Education in Oakland, California. Slack, who dubs her the Empress of the Evolutionary Forces, describes the center as “the only national organization dedicated solely to keeping evolution in public school classrooms and creationism out.”

As it happens, Scott and her deputy director, Glenn Branch, have edited their own book, a concise volume of counterarguments to ID titled *Not in Our Classrooms*. The book features essays by biologists, educators, philosophers, and theologians, each approaching the subject from a distinct perspective. Branch offers his own handbook for activists, and others attack ID not only as pseudoscience, but also as an exemplar of pandering politics, poor pedagogy, and tacky theology. The collection gives teachers plenty of ammunition for fighting verbal battles or answering students’ questions.



Of all the witnesses to testify at the trial, the chroniclers agree, the hero was Barbara C. Forrest, a philosopher and historian from Southeastern Louisiana University in Hammond. Forrest had co-au-

thored a damaging exposé of the creationists’ organizations, tactics, and goals: *Creationism’s Trojan Horse*. She and her co-author, Paul R. Gross, a biologist at the University of Virginia in Charlottesville, tracked the creationist movement’s history—through the group’s own internal documents—and revealed that its objective was never scientific, but had always been religious. The movement’s agenda is to manipulate the issue of evolution as a wedge that will lead to a change in the very definition of science. Supernatural causes would be allowed to replace the hated “naturalistic materialism” of science. And the creationists’ own, literal interpretation of the Bible would become the highest authority on morals, culture, and knowledge of the natural world.

For the trial, Forrest had also analyzed the Dover school board’s new proposed textbook, *Of Pandas and People*. Conducting a word search in successive versions, from the original draft in 1983 until its initial publication in 1989, she found the only substantive changes were to replace every instance of the words “creation” or “creationism” by the phrase “intelligent design.” (As the book defines it, “Intelligent design means that various forms of life began abruptly through an intelligent agency, with their distinctive features already intact.”) Tellingly, the switch had occurred after the creationists lost their 1987 appeal to the Supreme Court in *Edwards v. Aguillard*. The ruling in that case had blocked their attempt to introduce their faith-based “science” into Louisiana public schools.

When school board members took the stand, the depths of their ignorance appalled even those who might have been sympathetic. One woman cheerily testified that she knew nothing about either evolution or ID, but had voted to require the disclaimer because another school board member (an ex-cop and corrections supervisor) was “in law enforcement.” Reading Chapman’s account, you can almost hear the author’s jaw drop when it dawns on him that “an auto repairman” (the school board chairman) had appointed the ex-cop, “a biblical literalist without a shred of knowledge,” to decide which books the kids should learn from—backed up unquestioningly by

"a woman who had no curiosity about anything, even her most deeply held beliefs."

In the final moments of the trial, one of the plaintiffs' attorneys, Patrick Gillen, asked the judge a question: "Your Honor . . . by my reckoning, this is the fortieth day since the trial began and tonight will be the fortieth night, and I would like to know if you did that on purpose." Jones, smiling at the allusion to the length of time Noah's ark was tossed about in the Great Flood, instantly replied: "Mr. Gillen, that is an interesting coincidence, but it was not by design." And Matthew Chapman got his book title.

In the end, Judge Jones ruled against the school board, concluding that ID was grounded in a particular sectarian religion, not in science, and thus violated the Establishment Clause of the First Amendment. It is worth noting the stern tone of his concluding opinion:

It is ironic that several of these individuals, who so staunchly and proudly touted their religious convictions in public, would time and again lie to cover their tracks and disguise their real purpose. . . .

. . . The breathtaking inanity of the Board's decision is evident when considered against the factual backdrop which has now been fully revealed through this trial. The students, parents, and teachers of the Dover Area School District deserved better than to be dragged into this legal maelstrom, with its resulting utter waste of monetary and personal resources.

One thing about creationists, though: they constantly evolve. Over the years they have repeatedly reinvented themselves: from fundamentalists to creationists, to creation scientists, and now to ID scientists. The draft of *Design of Life*, essentially *Of Pandas and People* under a new title, includes a new phrase—"sudden emergence"—for another old idea, that of the spontaneous appearance of species by Divine fiat. An attorney for the plaintiffs read the definition for the court: "Sudden emergence holds that various forms of life began with their distinctive features already intact, fish with fins and scales, birds with feathers and wings, animals with fur and mammary glands." He then commented to the judge, "Hopefully we won't be back in a couple of months for the sudden emergence trial." "Not on my docket," said Jones, "let me tell you."

The battle no doubt will go on, but there may be one saving grace in the fabric of American culture: vast apathy. Attempting to interview teenagers about the case, Chapman discovers that many have absolutely no interest in the controversy. Slack finds the kids he speaks with equally clueless. "So this is the front line of America's

culture war," he writes, "pimpily kids who don't have the foggiest idea, or care much, if at all, what natural selection or 'irreducible complexity' are, let alone which one suggests a better explanation for the diversity of life on Earth."

During a recent boat cruise, on which I lectured about Darwin's voyage as we retraced some of his steps through the Galápagos Islands, I met a practicing Christian named Frank Wheeler. Wheeler has wide contacts with Christian philanthropic and other groups, and he genially wrote to me after our cruise: "During nearly twenty-seven years of participation in Christian organizations, I cannot recall any discussions of evolution or how it and other science might be in conflict with Bible teachings." Since returning from our trip, he continues,

I have sent a number of e-mails to a wide group of people from many walks of life, including several pastors, and they generally share my views that most American Christians are both "evolutionist and creationist" and see no conflict. If God set the world in motion in a way that opened the door for living things to evolve, most seem to think this was even more amazing and awe-inspiring than creating at the snap of a finger. . . . Most of us are more concerned about helping people improve their lives than in a literal interpretation of Genesis.

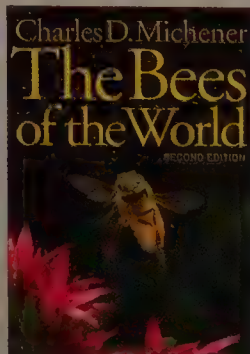
After all the hoopla, the drained emotions, and the wasted money, in the immortal words of Yogi Berra, "It's déjà vu all over again." It's the same story that played out in the Scopes trial of 1925, and more than a century and a half ago, when the English novelist Samuel Butler accused Charles Darwin of single-handedly depriving mankind of faith, hope, and purpose. But sixteen years after Darwin's death, perhaps with his longtime adversary in mind, Butler penned an extraordinary sonnet about immortality called "The Life After Death." Its concluding lines seem eerily prescient, reminding us that though the players change, the game remains eternally the same:

We shall not argue saying "'Twas thus" or "Thus,"
Our argument's whole drift we shall forget;
Who's right, who's wrong, 'twill all be one to us;
We shall not even know that we have met.
Yet meet we shall, and part, and meet again,
Where dead men meet, on lips of living men. □

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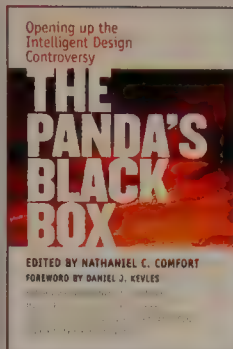
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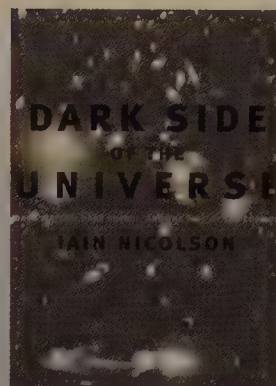


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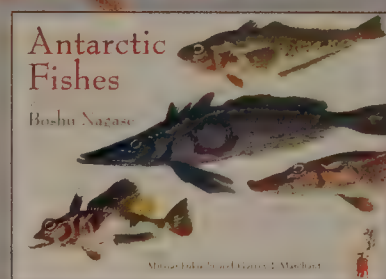
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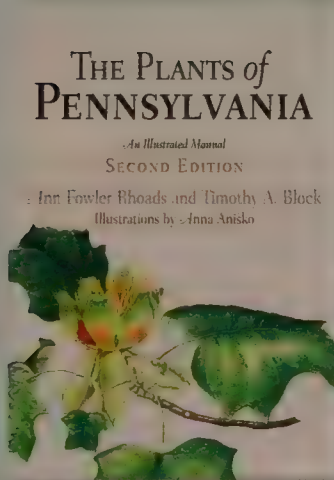


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THE SKY IN JUNE

By Joe Rao

Mercury is easy to find at dusk as June begins. Look for it about twenty-two degrees to the lower right of Venus (the width of your fist held at arm's length is roughly ten degrees across the sky). Mercury appears at magnitude +0.5 and sets just before the end of evening twilight. On the 2nd it reaches its greatest eastern elongation, or apparent angular separation from the Sun: twenty-three degrees. The planet is still as much as fifteen degrees above the horizon at sunset. A week later, on the 10th, it sets an hour and a half after the Sun, but by then it is also much dimmer, appearing at magnitude +1.5. From then on the planet fades rapidly. It passes inferior conjunction, roughly in line between Earth and the Sun, on the 28th.

Venus is by far the most brilliant evening "star" in the west after sunset. Sharp-eyed observers might even pick it out a little north of due west as the Sun sets. The interval between sunset and Venus-set shrinks from more than three hours at the start of the month to less than two and a half hours by month's end. In a telescope the planet is rapidly waning even as it grows in size, the telltale signs that Venus is swinging toward us along its orbit. Meanwhile, the planet is brightening by some 30 percent, reaching magnitude -4.5 by early July.

By pure geometry, Venus should appear half illuminated on the 9th, when it reaches its greatest elongation from the Sun. But its actual observed half phase, or "dichotomy," will likely appear some days earlier, though nobody knows exactly why. Thereafter Venus becomes a crescent that noticeably thins and lengthens. On the evening of the 18th a slender crescent Moon appears to hover almost midway between Venus (to its lower right) and Saturn (to its upper left). And at the end of the month Venus itself has a close encounter with Saturn (described under "Saturn").

Mars rises before 3 A.M. local daylight time on the 1st and an hour earlier than that by the 30th. Throughout the

month it races eastward against the stars, crossing from the constellation Pisces, the fish, into the constellation Aries, the ram, on the 27th. Mars is the bright orange "star" below and to the right of the Great Square of the constellation Pegasus, the winged horse, as dawn breaks at the start of the month. For the rest of the month it lies well below the stars of the constellation Andromeda, the chained princess.

Jupiter, glaring regally at magnitude -2.6, passes opposition to the Sun on the night of the 5th. After Venus sets, it is by far the brightest starlike object in the sky. It dominates the southeast during the early evening. Then, accompanied by the stars of the constellation Scorpius, the scorpion, with its ruddy heart, Antares, this magnificent planet treks across the southern sky all night before setting around dawn. But even at a respectably bright magnitude of +1.1, Antares is only about a thirtieth as bright as Jupiter.

Saturn lies in the constellation Leo, the lion, and appears in the western sky at dusk at magnitude +0.5. On the 1st, the planet sets more than four hours after the Sun; by the 30th, Saturn sets soon after evening twilight ends. Late in the month Venus, a hundred times brighter than Saturn, approaches from the west, coming within about three-quarters of a degree directly below the ringed planet on the 30th.

The **Moon** is at last quarter on the 8th at 7:43 A.M. It wanes to its new phase on the 14th at 11:13 P.M. and waxes to first quarter on the 22nd at 9:15 A.M. The June full Moon, sometimes called the "Strawberry Moon," takes place on the 30th at 9:49 A.M.

The **solstice** takes place on the 21st at 2:06 P.M. Summer officially begins in the Northern Hemisphere, winter in the Southern Hemisphere.

Unless otherwise noted, all times are eastern daylight time.



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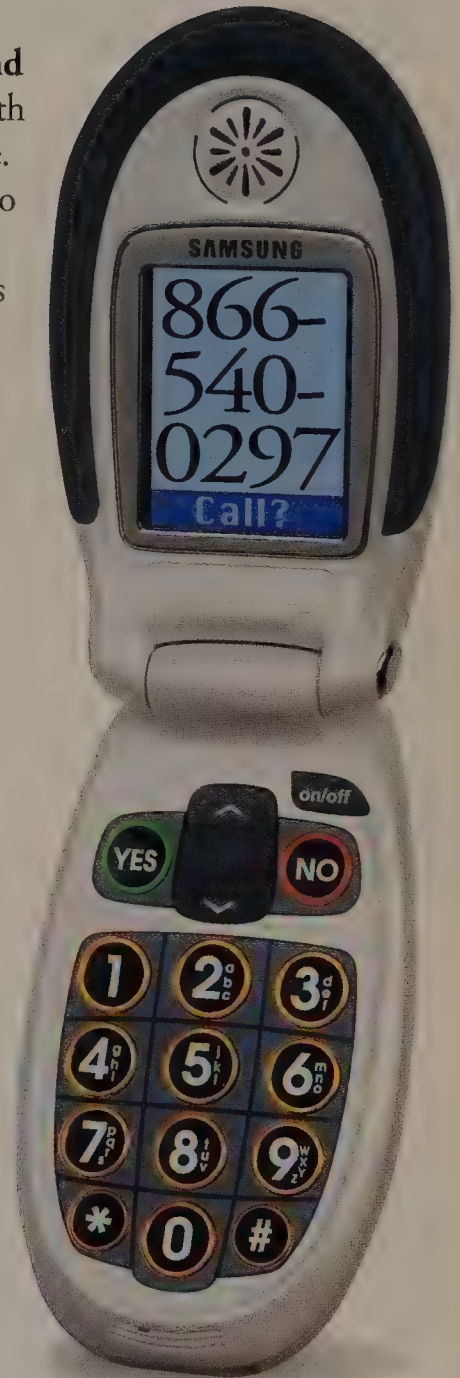
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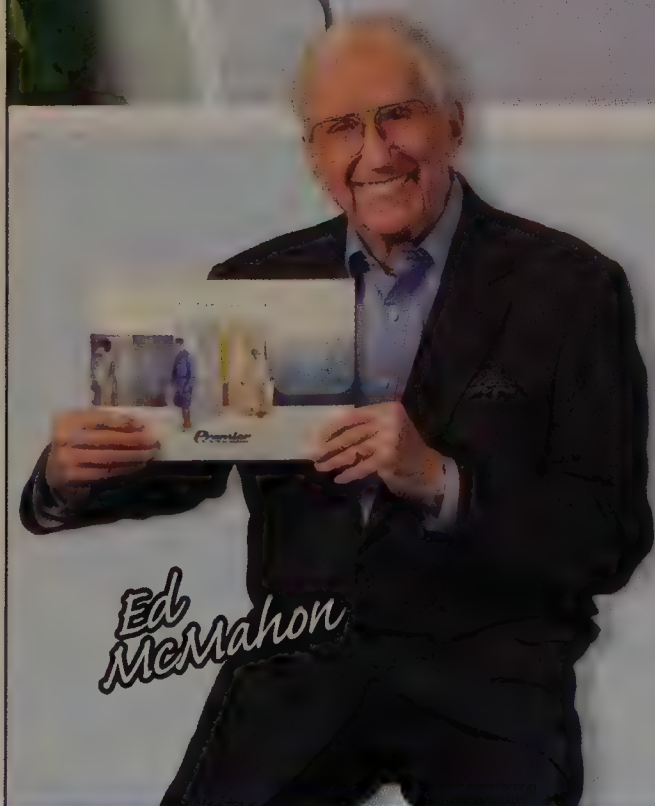
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Dr. Bart D. Ehrman is the James A. Gray Professor and Chair of the Department of Religious Studies at The University of North Carolina at Chapel Hill. He received his Masters of Divinity and Ph.D. from Princeton Theological Seminary. He has won several teaching awards, including the Students' Undergraduate Teaching Award and the Bowman and Gordon Gray Award for Excellence in Teaching. Professor Ehrman has written or edited more than 15 books, including the New York Times bestseller, *Misquoting Jesus*, and *Jesus: Apocalyptic Prophet of the New Millennium*.

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A Cool Young Star

*A distant nova dazzles with its beauty.
But where's the missing white dwarf?*

By Charles Liu

In January 2002, a previously unremarkable star—one of the distant stars forming the hazy band known as the Milky Way—suddenly flared up. The star, in the direction of the constellation Monoceros, the unicorn, became hundreds of thousands of times more luminous than our Sun, and briefly claimed the title of the most luminous star in our galaxy. Yet even at its brightest, the star was barely visible to the unaided eye from Earth. Four months after its initial flare-up it had settled back to its original brightness, roughly a ten-thousandth of its peak luminosity.

We astronomers call such a powerful stellar eruption a nova (Latin for “new”)—not to be confused with a supernova, in which a star literally blows itself apart. But V838 Mon, as this star-gone-nova is known, quickly showed that it was a one-horned horse of a different color—not at all like your typical nova. Soon some media outlets were comparing it to Vincent van Gogh’s painting *The Starry Night*, with its lustrous round stars encircled by rings of concentric brushstrokes. Today, V838 Mon has become one of the most closely studied single stars

in our galaxy, in large part because of the extraordinary way it lit up the dust that surrounds it.

But the star is cool too—literally, as stars go. In fact, it’s almost too cool to be a star, and not nearly as hot as the stars that undergo typical, so-called classical nova eruptions. At an international astronomy conference devoted to this one object, held last spring in the Canary Islands, a fascinating hypothesis was put forward: could the eruption of V838 Mon have been caused not by the flare-up of a single star but by the collision of two stars?

What causes a nova to erupt? Classically, the process begins as two stars orbit each other in a binary-star system. One of the two stars might be a mature star like our Sun. The other star is typically a white dwarf—a compact remnant left over after a sunlike star has ceased its thermonuclear activity. The two stars become locked in a tight gravitational embrace—usually with an orbital period of a few hours to a few days. The white dwarf has about the same mass as the sunlike star, but it’s a hun-

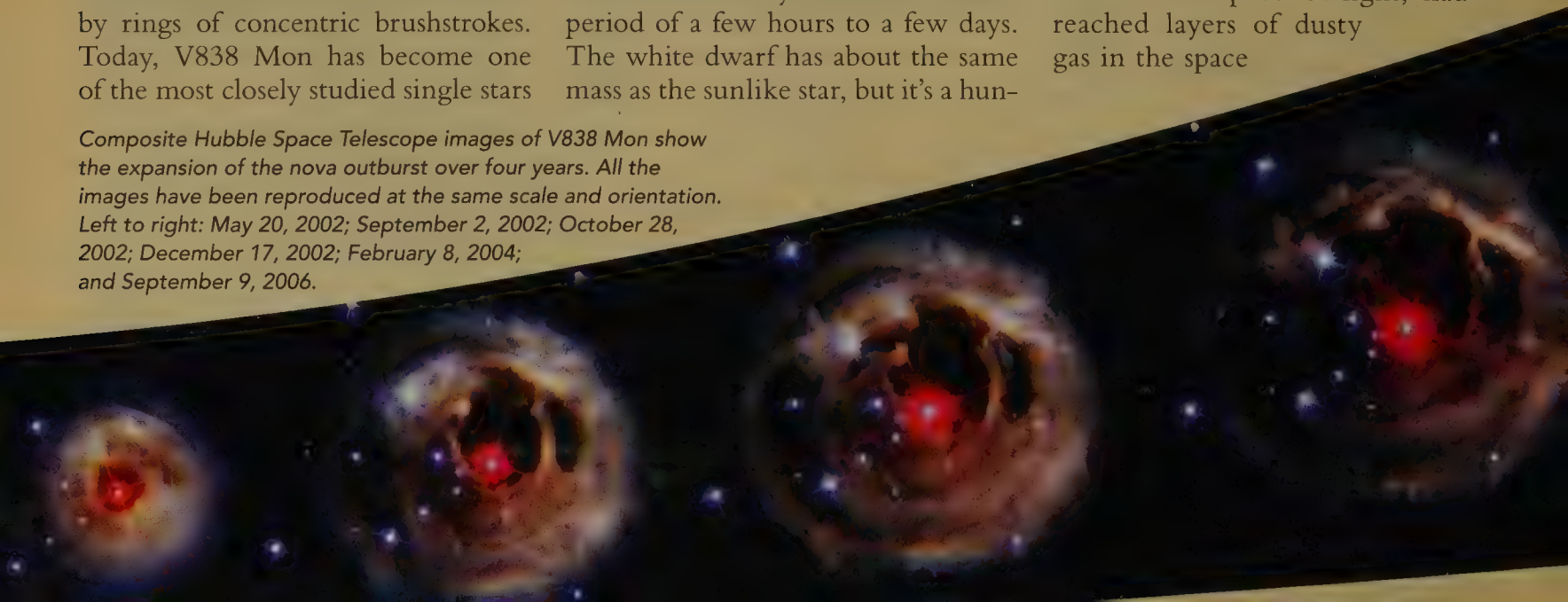
dred times smaller and a million times denser—a teaspoon of white-dwarf material weighs several tons. Its powerful gravitational field tugs on the outer gaseous layers of its companion, drawing off a stream of stellar gas.

As the captured gas builds up on the surface of the white dwarf, the surface temperature and pressure go up until they reach a critical point. The gas detonates in a thermonuclear flash, with the power of trillions upon trillions of terrestrial H-bombs. Matter from both stars, glowing brightly from the explosion, is blasted into space. As the glow gradually fades, the hot white dwarf sometimes becomes briefly visible at the core of the explosion. Then the cycle begins anew: gas continues to rain down onto the white dwarf from the sunlike star, setting the stage for another nova years, centuries, or even millennia later.

Because there aren’t enough professional astronomers in the world to discover and monitor all the novae that take place, dedicated amateurs play a critical role in finding and studying novae. So it was not surprising that an amateur astronomer, Nicholas J. Brown of Quinns Rock, Western Australia, was the first to see V838 Mon, on the evening of January 6, 2002.

Six weeks later, a team led by Arne Henden at the U.S. Naval Observatory in Flagstaff, Arizona, observed a stellar bonus: the flash of radiation from the “new” star, blasting outward at the speed of light, had reached layers of dusty gas in the space

Composite Hubble Space Telescope images of V838 Mon show the expansion of the nova outburst over four years. All the images have been reproduced at the same scale and orientation. Left to right: May 20, 2002; September 2, 2002; October 28, 2002; December 17, 2002; February 8, 2004; and September 9, 2006.



around the star. Some of the dust grains, aligned just right, acted like countless angled mirrors, collectively reflecting part of the outward-radiating light toward us. Here on Earth, astronomers could watch a progression of “light echoes” as the outburst radiated into space [see the series of composite images below].

Beyond the breathtaking beauty of its light echoes, V838 Mon is also undergoing rigorous scientific analysis. The first thing to measure was the distance to the star. Usually that is a pretty tough number to get—it’s not as if you can run a tape measure out there. But the expanding radius of the echoes marked the progression of light away from the explosion, and by timing the echoes, astronomers determined that the distance to the nova is almost exactly 20,000 light-years. That implied that V838 Mon at its peak brightness, back in early February 2002, was some 600,000 times more luminous than the Sun!

Here’s where the enigma began. The astronomers monitoring V838 Mon, expecting to see the standard pattern for classical novae, watched and waited for the hot white-dwarf system to reveal itself after the smoke

had cleared. But it never did. Instead, as time went on, V838 Mon just got cooler. The most recent observations suggest it has become cooler than the coolest ordinary stars, and now is only as warm as a typical “failed star,” or brown dwarf. If there’s no white dwarf in the system, what caused the explosion? A number of hypotheses have been put forward, most of which propose one of two competing explanations. Either the white dwarf remains obscured in some way—after all, the light echoes show that dust is all around the region—or a previously unknown kind of explosion has taken place on the white dwarf’s surface.

But now a study by Melike Afar of Ege University in Izmir, Turkey, and Howard E. Bond of the Space Telescope Science Institute in Baltimore, Maryland, has thrown cold water on both those explanations. Spectroscopic data from the region of space around V838 Mon revealed that the star system that likely birthed the nova is actually part of a small star cluster, whose stars all formed about 25 million years ago. That’s only a small fraction of the time needed for a star

to become a white dwarf. In other words, the time frame suggests that there is no white dwarf in the V838 Mon system at all. What then caused the eruption?

The evidence suggests a seemingly outlandish explanation: could two stars, neither one very bright, or one not-very-bright star and a giant planet, have collided? If the two bodies merged rapidly, any ongoing, ordinary thermonuclear fusion would be overwhelmed by an influx of fresh fuel. On a cosmic scale, it would be like flooding a campfire with a tanker truck’s worth of gasoline.

A lot more work will need to be done before the idea of a “stellar splash of fuel” can be confirmed or ruled out. Until then, astronomers will have to wonder whether this cosmic “starry night” was produced by the meticulous brushstrokes of a classical master—or by the maniacal paint swirls of a modernist.

CHARLES LIU is a professor of astrophysics at the City University of New York and an associate with the American Museum of Natural History.



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Free Lunch

By Robert Anderson

My Los Angeles neighborhood teems with scavengers: coyotes, crows, raccoons, and rodents. Recently I watched as several dozen vultures, those icons of the ilk, circled lazily overhead. Eyeing them suspiciously, I wondered if their Hollywood image was true—had something large died nearby? Later, an ornithologist friend reassured me that the birds were not hovering over a carcass. The "Questions and Answers" section of the Turkey Vulture Society's Web site (vulturesociety.homestead.com/Attract.html) confirmed my friend's assertion: the flock of vultures, known as a "venue," had no immediate plans to dine. Instead it had formed a "kettle," so named for the birds circling upward on a thermal of rising hot air, reminiscent of bubbles that rise in a kettle of boiling water.

Inspired to delve more deeply into the lives of scavengers, I learned that among the vertebrates there are few true scavengers—animals that feed solely on carrion. But other animals populate a vast gray area. Predators such as lions readily chew on someone else's abandoned kill; animals such as raccoons, regarded mainly as scavengers, also hunt prey. True scavengers are common, however, in the invertebrate world, particularly on the deep ocean floor.

All diners on the dead perform a valuable service by cleaning the planet of rotting and often diseased flesh, thereby recycling nutrients into the food web. The adaptations that enable them to fill their niche are as remarkable as anything in nature.

Please go to our Natural History Web site (www.naturalhistorymag.com), where I report on more tidbits, scavenged from various sites on the Internet, about these remarkable animals.

Robert Anderson is a freelance science writer living in Los Angeles.

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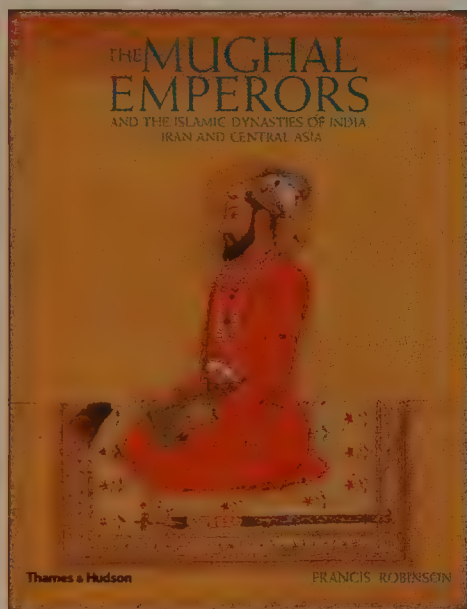
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LETTERS

(Continued from page 10)

GIL MOR REPLIES: That might be a significant factor, but to evaluate that possibility, one would have to determine whether women who live longer are more likely to have been pregnant at some time in their lives. And one would have to control not only for differences between women and men that might affect their differential longevity (such as occupational stress), but also for whatever differences lead some women to get pregnant during their lives, and others not.

The Eyes Have It

A caption that accompanies Jennifer A. Mather's article on octopuses ["Eight Arms, with Attitude," 2/07] states that the octopus eye "is a remarkable example of convergent evolution [with the vertebrate eye] despite more than 1.2 billion years of independent evolution." But to my knowledge, every animal species examined so far owes the development of its eye to the *Pax-6* gene, a gene of remarkable persistence.

Frank M. Sturtevant
Sarasota, Florida

THE EDITORS REPLY: Frank Sturtevant is correct; we fell into repeating an outdated example of convergent evolution. According to Sean B. Carroll, a molecular biologist at the University of Wisconsin-Madison, "One of the most surprising discoveries from the study of the evolution of animal development is that all sorts of eyes form under the control of a set of regulatory proteins, including *Pax-6*, which date to a common ancestor of vertebrates, arthropods, and cephalopods that lived at least 550 million years ago."

Natural History welcomes correspondence from readers. Letters should be sent via e-mail to nhmag@naturalhistorymag.com or by fax to 646-356-6511. All letters should include a daytime telephone number, and all letters may be edited for length and clarity.

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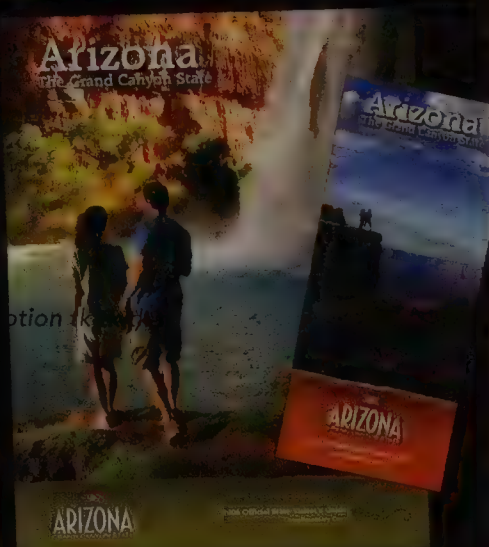


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At the Museum

AMERICAN MUSEUM OF NATURAL HISTORY



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Sniffing Out Polar Bears

Dogs may be (hu)man's best friend, but at least one canine is the best friend a polar bear could ever have. Quinoa, a two-year-old Dutch shepherd trained by graduate student Linda Gormezano to sniff out polar bear scat, is helping obtain genetic samples that may shed light on this threatened mammal's population size, structure, and behavior near Hudson Bay in northeastern Canada.

Gormezano began her Ph.D. work at the American Museum of Natural History through City University of New York (CUNY) in 2004, initially focusing on extracting DNA samples from coyote scat to study pack structure in Westchester County. The goal, she said, was also to develop new ways of identifying an animal repeatedly without putting it through the stress of being darted and tagged. She had heard of dogs being used before to find scat samples and passively "tag" animals and began to think she could do the same.

During a trip to Wapusk National Park in Manitoba with Robert F. Rockwell, her advisor and Research Associate in the Museum's Department of Ornithology, they both realized



ROBERT F. ROCKWELL

Gormezano and Quinoa on the trail of polar bears near Churchill, Manitoba

that applying Gormezano's tagging techniques to polar bears represented the next logical step in her research. The idea of using a dog became even more compelling, as it would be able to cover a lot of tundra and gather the large number of samples needed to do her work.

In 2005, Gormezano bought six-month-old Quinoa, who had flunked out of police training because he was more of a lover than a fighter. For the next year, she used samples of coyote and polar bear scat to teach Quinoa to seek out the scent of each in the wild. His reward when he finds either is a tennis ball, but his work is anything but play—polar bears in Wapusk are believed to be heavily threatened by global warming-induced changes to their habitat.

"When Quinoa's out in the field, his nose is glued to the ground," said Rockwell. "He's serious about this. Linda and Quinoa are opening up a whole new frontier in tracking and monitoring animal populations."



An uncommon summer gathering of polar bears in Wapusk National Park. Gormezano's work may help reveal behavioral changes linked to global warming.

ROBERT F. ROCKWELL

EVERYONE WANTS TO KNOW SOMETHING

WWW.AMNH.ORG

No matter how many hours children spend at the American Museum of Natural History, they often leave hungry for more. Frankly, that's our goal, to spark their curiosity and inspire a lifetime habit of learning. So, to extend the Museum experience, we offer Ology, an award-winning Web site filled with fun activities for kids interested in science.

Created by the National Center for Science Literacy, Education, and Technology, part of the Museum's Education Department, the site offers layer after layer of learning as only the Web can—with interactive games, quizzes, puzzles, polls, and stuff to do away from the computer.

Children can set up their own privacy-protected home pages with a unique, jazzy, nature-oriented Ology member name (think "prickly

platypus" or "happy newt") where they can collect information cards and create projects to submit to the Ology Hall of Fame. "Meet the Ologists" describes the people doing science at the Museum, and what first got them interested in their fields, and includes a team of kid Ologists. The site also contains a helpful teacher's guide for grades 3 through 8.

"Ology is about the real world," the site explains. "And nothing is more fascinating than what's real." Log on, and we think you'll agree. Ology can be reached from the Museum's home page at www.amnh.org or directly at ology.amnh.org.



Food for Thought

As with all new endeavors, when the Museum started its "Adventures in the Global Kitchen" series highlighting cultures through cuisine, there were a few bugs to work out—literally! The exciting first program offered up such delights as scorpion sushi, waterbug canapés, and cricket pizza. Bringing new meaning to "fusion food," a Museum entomologist worked with a chef and a planner for the Explorers Club Annual Dinner to turn ethnic recipes in which insects were the star ingredient into dishes worthy of a four-star restaurant—and daring diners.



Dandelions are tasty in salads or as tea or wine.



A Museum visitor prepares to enjoy a mealworm at the inaugural Global Kitchen program.

That was May 2004, and since then, there have been more than a dozen amazing evenings of talks, tastings, and Q&A sessions, all designed to

amplify the Museum's mission to share ideas about human cultures and the natural world.

Over the past three years, Adventures in the Global Kitchen has explored the cuisines of Brazil and China; the historic roles of rum, beer, and wine in various cultures; the significance of corn in the American food chain; and special dishes associated with Mexico's Day of the Dead. Earlier this year, a panel considered the evolution of human taste and smell, while more recent programs focused on the dandelion, honey, mushrooms, and winemaking.

Often, chosen subjects tie in with concurrent Museum programs and exhibitions. The much-publicized first event coincided with the showing of

remains on view until August 19.

Sea Serpent Stew and Dragon Brew: Fanciful Foods of the Middle Ages, scheduled for Tuesday, June 26, celebrates the new exhibition *Mythic Creatures: Dragons, Unicorns, and Mermaids*, on view through January 6, 2008. Francine Segal, noted food historian, will discuss foods and dining customs of the Middle Ages, when chefs created improbable culinary creatures like the cockatrice, which was part capon, part pig.

Also upcoming is *Insatiable* with Gael Greene, Thursday, July 7, an evening of tales and tastings with the long-time author of "The Insatiable Critic" column for *New York* magazine and cofounder and board chair of Citymeals-on-Wheels.

This series has been extremely popular, especially since tastings are included with every lecture; many programs sell out well in advance. Stay tuned for further Adventures in the Global Kitchen!

Bugs! a giant-screen film about the insect world, just as the second in the series, *Fiery Foods* (southwestern cuisine), in December 2004, was inspired by the exhibition *Totems to Turquoise: Native North American Jewelry Arts of the Northwest and Southwest*. Similarly, *Golden Sake*, in January this year, connected to the exhibition *Gold*, which



Viniculture was a popular Global Kitchens topic.

PEOPLE AT THE AMNH

Mick Ellison

Senior Principal Artist
Division of Paleontology



MARNI FYLLING-ELLISON

It takes imagination—and dogged attention to detail—to draw a fleshed-out prehistoric creature, something no one has ever seen. Before Mick Ellison even attempts to render a particular specimen, he sculpts a clay model, working with the fossil record and scientific data, so he can first "visualize it in 3-D." To complete one of his most famous illustrations—a feathered dinosaur from China's Liaoning Province—Mick scoured New York's Garment District for the just-right rooster hackles to match an impression literally cast in stone. "The fossils yield a lot of clues," he says.

Mick also photographs fossils as they're discovered in the field, documents expeditions, makes maps and charts, and does anatomical restorations and reconstructions. Besides China, his work has taken him to Japan, Thailand, Myanmar, Laos, and Mongolia's Gobi Desert. Two fossils unearthed there during the Museum's joint expeditions with the Mongolian Academy of Sciences bear Mick's name: the sauropod *Erketu ellisoni*, for which he shares the billing with a Mongolian deity, and a lizard, *Temujinia ellisoni*, whose genus name refers to Genghis Khan.

Mick will never forget the ad that drew him to the Museum in 1990. "Museum seeking artist to work in paleontology. Must be willing to travel on field expeditions internationally." It was a dream come true for a 20-something art school graduate who'd spent his childhood doodling dinosaurs. "I love that I can draw and travel and get paid for it," he says.

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY 

www.amnh.org

EXHIBITIONS

Mythic Creatures: Dragons, Unicorns, and Mermaids

Through January 6, 2008

Tracing the natural history roots of some of the world's most enduring mythological creatures, *Mythic Creatures* highlights legendary beings of land, sea, and air. Cultural artifacts bring to light surprising similarities—and differences—in the ways peoples around the world have depicted these beings, and fossil specimens suggest a physical basis for the many forms they have taken.

Mythic Creatures: Dragons, Unicorns, and Mermaids is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with The Field Museum, Chicago; Canadian Museum of Civilization, Gatineau; Australian National Maritime Museum, Sydney; and Fernbank Museum of Natural History, Atlanta. *Mythic Creatures* is proudly supported by MetLife Foundation.

Frogs: A Chorus of Colors

Through September 9, 2007

This delightful live-animal exhibition introduces visitors to the colorful and richly

diverse world of frogs, exploring their biology, ecology, and conservation.

Frogs: A Chorus of Colors is made possible, in part, by the Eileen P. Bernard Exhibition Fund. This exhibition is presented with appreciation to Clyde Peeling's Reptiland.

Gold

Through August 19, 2007

This glittering exhibition explores the captivating story of the world's most desired metal. Extraordinary geological specimens, cultural objects, and interactive exhibits explore and illuminate gold's timeless allure.

Gold is organized by the American Museum of Natural History, New York (www.amnh.org), in cooperation with The Houston Museum of Natural Science. This exhibition is proudly supported by The Tiffany & Co. Foundation, with additional support from American Express® Gold Card.

Undersea Oasis: Coral Reef Communities

Through January 13, 2008

Brilliant color photographs capture the dazzling invertebrate life that flourishes on coral reefs.

Beyond

Through April 6, 2008

Exquisite images from unmanned space probes take visitors on a journey through the alien and varied terrain of our planetary neighbors.

The presentation of both *Undersea Oasis* and *Beyond* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.



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GLOBAL WEEKENDS

Mythic Festival

Sunday, 6/24, 1:00–5:00 p.m.

A family festival tying together cultural, historical, and scientific perspectives on mythic creatures. For details, visit www.amnh.org/mythic.

Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, the New York City Council, and the New York City Department of Cultural Affairs. Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

LECTURES

The Griffin and the Monster of Troy

Thursday, 6/14, 7:00 p.m.

Folklorist Adrienne Mayor investigates the link between mythical creatures and the fossil remains of extinct animals.

Seeing beneath Mount Everest

Thursday, 6/14, 7:00 p.m.

Geologist Anne Sheehan, University of Colorado at Boulder, discusses her

research on the faults beneath the Himalayas.

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ADVENTURES IN THE GLOBAL KITCHEN

LECTURES AND TASTINGS

Insatiable with Gael Greene

Thursday, 6/7, 7:00 p.m.

An evening of tales and tastings with Gael Greene, longtime author of "The Insatiable Critic" column for *New York* magazine and cofounder and board chair of Citymeals-on-Wheels.

Sea Serpent Stew and Dragon Brew

Tuesday, 6/26, 7:00 p.m.

Francine Segal, food historian, discusses foods and dining customs of the Middle Ages inspired by mythical creatures such as dragons, griffins, and sea serpents.

FIELD TRIPS

Up the Hudson River

Tuesday, 6/19, 6:00–9:00 p.m.



D. FINNIN/AMNH

This "life-size" model of a roc, an enormous, legendary bird of prey, swoops towards visitors in *Mythic Creatures*.



ROSE CENTER FOR EARTH AND SPACE

Sets at 6:00 and 7:30 p.m.

Friday, June 1

Visit www.amnh.org for lineup.

The 7:30 performance will be broadcast live on WBGO Jazz 88.3 FM.

Learn about the geologic and cultural history of the lower Hudson valley on this three-hour cruise.



The Little Red Lighthouse is a landmark on the Hudson River in New York City.

Evening Bat Walks in Central Park
Friday, 6/15, 8:30 p.m.

K. BREW/AMNH

Friday, 6/22, 8:30 p.m.
Join the New York Bat Group for a bat walk through Central Park.

FAMILY AND CHILDREN'S PROGRAMS

Dr. Nebula's Laboratory: Mythic Stories and Tales
Sunday, 6/24, 2:00–3:00 p.m.
(For families with children ages 4 and up)
Join Dr. Nebula's apprentice, Scooter, as she explores mythic stories and tall tales in this interactive show.

This program is made possible, in part, by an anonymous donor.

AMNH ADVENTURES SUMMER CAMPS

Fossils and DNA
Monday–Friday, 6/18–22,
9:00 a.m.–4:00 p.m. (For children entering grades 2 or 3)

AMNH Sampler Camp
Tuesday–Thursday, 6/26–28,
9:00 a.m.–1:00 p.m. (For children entering grade 1)

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply. All programs are subject to change.

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T. GOELMAN/AMNH

Two campers show off their Ocean Adventures projects.

Ocean Adventures
Tuesday–Thursday, 6/26–28,
9:00 a.m.–3:00 p.m. (For children entering grades 2 or 3)

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME
Virtual Universe

Exploring the Orion Nebula
Tuesday, 6/5, 6:30–7:30 p.m.

Celestial Highlights
Summer Night Delights
Tuesday, 6/26, 6:30–7:30 p.m.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions
Journey into deep space to explore the hypersonic impacts that drive the formation of our universe. Narrated by Robert Redford.

Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum. Made possible through the generous support of CIT. *Cosmic Collisions* was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

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Eye of the Dragon

By Laurel Kendall

In the days before the Vietnamese Mid-Autumn Festival (Tết Trung Thu), the market along Hanoi's Hang Ma Street is resplendent with brightly colored toys, masks, and paper and plastic lanterns. Struggling to keep my balance in the press of the crowd, I look down and see a small red unicorn staring up at me. The dark brown eyes of a child, about five or six years old, peer out through the open mouth of his mask, and we share a shy smile. For now, he is an Asian unicorn with a fur beard and a curved horn on the top of his head. Similar masks, made of recycled paper and paint, are piled on the stalls that line the street, competing with plastic action-hero masks from China.

Insistent gongs and the steady throb of a big drum announce the arrival of a more spectacular unicorn. He prances into view, shaking his span-gled coat, nodding his horned head high and low, and lunging playfully at the crowd. The children squeal with delight while the two dancers, "head" and



"tail" under a common coat, continue down the street. One of the four auspicious beasts of ancient times, the unicorn dances at the festival to bring good fortune. Eastern mythology relates that the unicorn appears only when the world is ready for the birth of a sage. Legend has it that Confucius made the last sighting, just before his death in the fifth century B.C. In other words, no one alive now

has ever seen one—yet anyone who has been to a Mid-Autumn or New Year festival in Vietnam, China, Japan, or New York City has likely encountered a unicorn.

I recalled my visit to the Hanoi market when I worked as a member of the curatorial team for "Mythic Creatures: Dragons, Unicorns & Mermaids," a new exhibition for the American Museum of Natural History in New York City. How could we represent a "mythic creature"? How were we to talk about things that weren't "really" there? We would, of course, describe mistaken sightings, such as the rhinoceros that Marco Polo encountered on his way home from China and described as a unicorn. But as an anthropologist among biologists, I hoped we would not reduce all of our mythic creatures to other peoples' misunderstandings of the natural world. Our exhibition might also try to evoke the kind of playful wonder I had seen on that autumn day in Vietnam, when everyone knew that real dancers animated the unicorn costume. That was part of the enchantment.

For the exhibition we will have a unicorn mask like the one I saw in the market. We have also borrowed a mask and costume of the Balinese Barong Ket, a lionlike creature. The mask is the work of a master carver named Cokorda Raka Tisnu, of Singapadu Village in Bali. When he creates such a mask, Cokorda takes special care, knowing that it will be consecrated by a priest and inhabited by an otherwise invisible spirit. In Bali-



Vietnamese child wears a unicorn mask at the Mid-Autumn Festival market in Hanoi. Below left: A painted clay dragon represents one of the twelve animals of the East Asian zodiac; it was made by Hoang Ba Phat of Tu Khe Village, Vietnam.

nese temple festivals, the Barong Ket lopes through the village, brought to life through the combined skill of carver, priest, and dancers. As a protective deity, he restores order where Rangda the witch sowed chaos. Such is the artful work of culture.

The dragons that dance in parades for Chinese New Year are awakened in a ritual known as "eye opening": the leader of the troupe removes a red paper that covers the eyes, then dots the eyes and, subsequently, the entire costume with red cinnabar, bringing each part of the creature to life. Seven years ago the Wan Chi Ming Institute, practitioners of the Hung Gar style of Kung-fu in New York City's Chinatown, commissioned an enormous dragon from Hong Kong. When it arrived, they opened its eyes and immediately danced the awakened dragon around the block. That dragon is now retired from active duty, but it has an honored place in "Mythic Creatures." Meanwhile, a newly energized dragon will perform downtown.

Laurel Kendall is a curator in the division of anthropology at the American Museum of Natural History in New York City.

Getting your feet wet in Belize.



"We were hiking through the rainforest with our guide, Pablo, when the 100 foot tall trees over our heads opened in front of us. We were at a tiny lagoon at the Cave Branch River in Belize, starting a subterranean adventure called cave tubing.

Pablo told us some of the caves we were floating through were up to seven miles deep and a couple hundred thousand years old (Pablo knew his history and explained everything in perfect English). Each cave we passed through was different. My favorite was where the sparkling quartz crystals on the ceiling shimmered like a beautiful chandelier when it was hit by patches of sunlight.

Another cave we went through was like going to a spa. Pablo told us the subterranean mud we found on the walls made a great natural face mask. We couldn't resist the free beauty treatment!

As we came out of the cave system we were greeted by green jungle and bright sunlight bouncing off white limestone cliffs. It was awesomely beautiful, and we were sad this chapter of our great Belize adventure was coming to a close."

— Tiffany Piecewicz —

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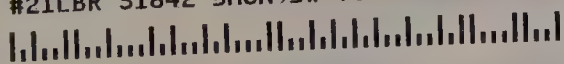
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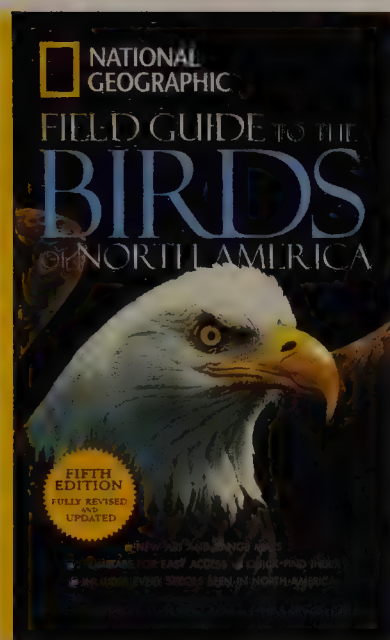
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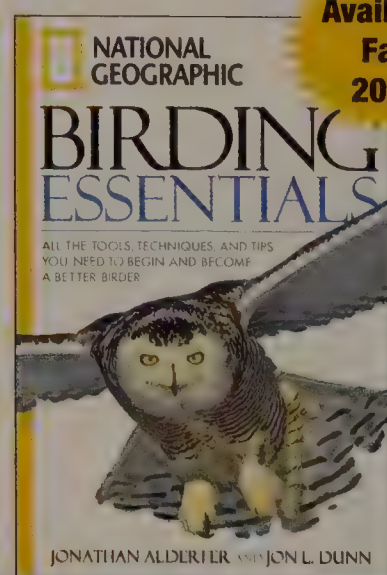
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TO TIMBUKTU



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In November, look for *National Geographic Birding Essentials*, an indispensable guide that teaches new enthusiasts how to get the most from bird watching. The entire collection features hundreds of birds, incredible illustrations, phenomenal photography, meticulous maps, and information you can trust—all of the qualities you expect from *National Geographic*.



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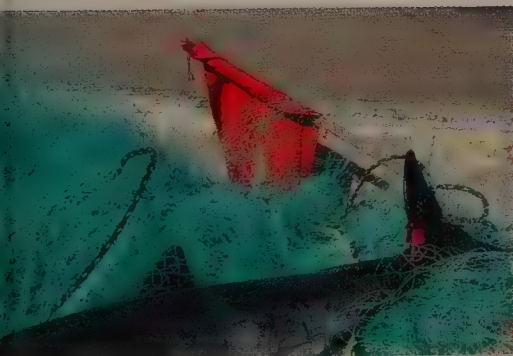
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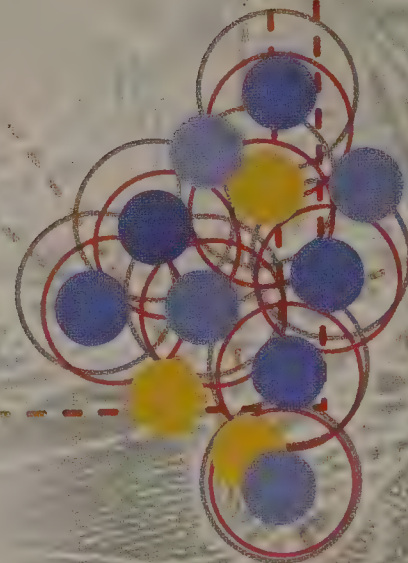
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THE NATURAL MOMENT

Laid-back in the Outback

Photograph by Mitsuaki Iwago





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ARIZONA
GRAND CANYON STATE

THE NATURAL MOMENT

◀ See preceding two pages



Dry, scorching days of summer call for long hours of lounging on both sides of noon. And in parts of central Australia, where the average rainfall is less than nine inches a year, warm-blooded animals must heed that call. Photographer Mitsuki Iwago kept cool, mostly by staying in his car to travel through Sturt National Park. Sturt lies in the northwest corner of New South Wales (NSW)—a hot, isolated place known as “Corner Country.” There, red kangaroos save their bounding and grazing for night, or at least for the edges of the day.

On his drive, Iwago happened upon this male red kangaroo, stretched out in the dirt, asleep in the midday heat. As Iwago tried to ease out of his car and around the back without startling the kangaroo, the animal “jumped to his feet and started to scratch himself with his sharp nails.” After a good deal of scratching and twitching, the male settled back down to his nap, and Iwago got his picture.

Red kangaroos usually travel in “mobs” of about ten: one male plus several females and young. So, perhaps the male that Iwago encountered was in search of a mob to control. There’s certainly no shortage of them to compete for: more than 2 million red kangaroos live in NSW. Because of the dense populations, hundreds of thousands of red and gray kangaroos, plus wallaroos, are culled every year for the sake of preserving local vegetation. Nevertheless, plans to cut back on the high numbers of kangaroos near Canberra, southeast of Sturt, are arousing some locals to a state far from repose. —Erin Espelie

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UP FRONT

Long Ago and Far Away

If you had to name a town, a landscape, a place so remote that getting there would take you to the ends of the earth, few would quarrel if you answered, “Timbuktu.” To many people, at least in the West, Timbuktu is the stuff of legend, far more remote and unreal than Garrison Keillor’s fictional Lake Wobegon. According to the BBC, a small survey made last year among young people in England found that a third of them did not think Timbuktu existed at all, and the other two-thirds regarded it as a mythical place.

Of course, Timbuktu is much more than just a romantic state of mind. It’s as real as the hot sand from the encroaching Sahara, as real as poverty and resignation, a city of 30,000 souls built a thousand years ago next to a vast floodplain of the Niger River, now a part of the West African nation of Mali. Shortly after we prepared our cover story for this issue, “Space, Time, and Timbuktu” (page 22), I spoke to Marq de Villiers about the time he spent in Timbuktu with his wife and coauthor Sheila Hirtle, doing the research for their forthcoming book, on which their article is based. (For a full audio recording of my interview with de Villiers, go to our Web site for the July/August issue, www.naturalhistorymag.com; a link to the interview will appear under the heading “Featured Story.”)

. . .

One of the most remarkable things about Timbuktu,” de Villiers told me, “is that the city was a major center of Islamic scholarship. There was a university in Timbuktu [the University of Sankoré] that rivaled the great centers of Islamic learning in Egypt and even in Mecca. In the fourteenth and sixteenth centuries scholars arrived from all over the Islamic world to study in Timbuktu. Today there are still substantial depositories of manuscripts and ancient libraries.”

So did Timbuktu represent a particular school of Islamic thought? Absolutely, de Villiers replied. The version of Islam that flourished in Timbuktu became a very liberal branch—the rough equivalent of the Jesuits among the Roman Catholics. “They were very tolerant of outsiders, and the intention of most of their schools and scholarship was essentially peacemaking . . . and accommodation—a position of tolerance that, as we know, is not universal in Islam.

“The sad thing about this today,” he continued, “is that Mali is so poor that many of the young people of Timbuktu and other cities go to the Gulf [Persian Gulf states] to get work and to study. Some of them, alas, get infected with the more fundamentalist, Wahhabi view of Islam.” Some of that, inevitably, has come back to Timbuktu. “There’s a big squabble going on in the town between the tolerant wing and the more fundamentalist wing of Islam, and it’s a fascinating case study. The fundamentalists regard the older and more tolerant people as un-Islamic.”

Perhaps Timbuktu is not so distant from the modern world after all.

—PETER BROWN

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In his twenty-five years as a nature photographer, **MITSUAKI IWAGO** ("The Natural Moment," page 2) has made award-winning photographs in more than seventy countries. He is the author and photographer of *Serengeti: Natural Order on the African Plain* (Chronicle Books, 1987), which he worked on from 1982 until 1984 while living with his family in Africa. His most recent book is *Animals on Earth*, published by Fukuinkan Shoten in Tokyo. He is now at work on a documentary series, *Mitsuaki Iwago's Nature World*, in partnership with the Japan Broadcasting Company (NHK). Go to his website (www.digitaliwago.com) for more of his images.



A husband-and-wife team who live in Port Medway, Nova Scotia, **MARQ DE VILLIERS** and **SHEILA HIRTLE** ("Time, Space, and Timbuktu," page 22) have collaborated on a number of books. Their latest joint effort, the basis for their article in this issue, is *Timbuktu: The Sahara's Fabled City of Gold*, which is being published in August by Walker & Company. Among their earlier collaborations

are *Sahara: The Life of the Great Desert* and *Into Africa: A Journey Through the Ancient Empires*. In sharp thematic contrast, they are also the authors of *Blood Traitors*, the saga of German immigrant families caught up in the American Revolution, and *Sable Island*, the story of an enigmatic sandbar off Nova Scotia. De Villiers was born in South Africa, and his first book, *White Tribe Dreaming*, was a history of the Afrikaners of South Africa. His other books include *Windswept: The Story of Wind and Weather*. A native Canadian, Hirtle is an editor and researcher with a background in fine art and design, marketing, and journalism. Her projects include a wide-ranging study of African art and music.

Coauthors **ROBERT L. PITMAN** and **LORENZO ROJAS-BRACHO** ("How Now, Little Cow," page 28) have both taken up the cause of the endangered vaquita, a porpoise that lives only in the northern Gulf of California. Pitman is a marine ecologist with the Southwest Fisheries Center of the National Oceanic and Atmospheric Administration in La Jolla, California, where he specializes in marine birds and mammals. His current research interests include the ecology of flying fish and the evolution of the Antarctic killer whale. With coauthors Thomas A. Jefferson and Marc A. Webber, he is completing a field guide, *Marine Mammals of the World*, which will be published this fall by Elsevier. Rojas-Bracho is a marine biologist at the National Institute of Ecology/Center for Scientific Research and Higher Education of Ensenada (CICESE) in Ensenada-Tijuana, Mexico, where he coordinates the National Marine Mammal Program. In recent years he has concentrated his time on research and conservation efforts to prevent the extinction of the vaquita. He is the founder and chair of the International Committee for the Recovery of the Vaquita.



Pitman



Rojas-Bracho

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LETTERS

Thanking the Stars

I am a single mother and as such, I often struggle with daily life in a big city where, as Langston Hughes once said, a nickel costs a dime. But tonight, for just a few minutes while I read Neil deGrasse Tyson's "The Cosmic Perspective" (4/07), I was lifted up to a higher place, where I was able to see that many of my daily worries are actually insignificant. A sense of peace came over me as I imagined the chemical elements inside my body being the same as those scattered all across the universe. How sad that in most of our barrios today the light created by our earthly activity has blocked

out our view of the stars. Perhaps if we could still see them, we could all remember how small we are. For now, I must be content with the gift afforded me by Mr. Tyson. Those words you labored over have touched at least this one soul.

*Franziska Castillo
Bronx, New York*

Neil deGrasse Tyson's 100th column is a brilliant reminder of why we should rediscover the awe of the universe that we all felt on seeing the Milky Way for the first time. I wish this article were required reading for every world government leader and anyone else who

thinks waving the flag is more important than the cosmos around us.

*Velo Mitrovich
London, United Kingdom*

Neil deGrasse Tyson's 100th article shows off his artistry for putting cosmic thoughts into words. This wasn't surprising to me, as I've been a fan for years. What I found enlightening were his thoughts in the preceding "Up Front" interview. His concerns about his writing process mirror those of people in the other arts—the jubilation and satisfaction, self-doubt about the next project, exhaustion, and ultimately, fulfillment. Mr. Tyson is a true artist.

Thanks for the inspiration.
*Mark Garro
Livingston Manor, New York*

NEIL DEGRASSE TYSON REPLIES: I am moved by the overwhelmingly positive response I have received to my 100th "Universe" essay. I try hard on these pages to bring the universe down to Earth. I am glad to know that I occasionally succeed.

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SAMPLINGS

Smelting Gun

The abundance of pre-Columbian bronze, copper, and silver artifacts in Peru indicates that the region was a center for metallurgy in the New World. But archaeologists have long been puzzled because they have never found remnants of smelting furnaces in the highlands of the Peruvian Andes, the source of much of the region's mineral reserves. Indeed, seventeenth-century Spaniards were long thought to have been the first metallurgists in the highlands. A new study, however, shows that pre-Columbian civiliza-

tions were smelting there after all: metallurgists started polluting a local lake with lead and other metals 1,000 years ago.

When metals were extracted from ore in ancient wind-drafted furnaces, small particles of floating debris would have settled in nearby bodies of water. To detect such ancient pollution, a team led by Colin A. Cooke, a graduate student of environmental science at the University of Alberta in Edmonton, hammered a three-foot-long plastic tube into the muddy floor of Lake Pirhuacocha, in Peru's Morococha mining region, and withdrew a cylinder of sediment.

Chemical analysis detected signs of smelting in sediments from as early as A.D. 1000, soon after the decline of the Wari Empire. Most of the early smelting produced copper and bronze. Lead pollution, a sign of silver production, turned up only after A.D. 1450, first during the Inca reign, later under European colonialism, and finally in modern Peru (a working mine and smelter stand nearby). Cooke thinks the missing furnaces were simply destroyed by landslides, which plague the highlands. (*Environmental Science & Technology*)

—Brendan Borrell

Lake Pirhuacocha

Escape from the Vortex

Black holes draw matter in, but they can also send a little of it flying out through space, borne on winds of hot gas that develop when matter is superheated by the black hole's own radiation. Some astronomers have proposed that those winds might help scatter such "heavy" elements as carbon and oxygen—the stuff of planets and life—across vast intergalactic distances, perhaps seeding empty parts of the universe with the materials to form planets. New observations provide the first experimental evidence in support of the seeding hypothesis, but they also hint

that the effect might be considerably more local than originally proposed.

A team of astronomers led by Yair Krongold

of the National Autonomous University of Mexico in Mexico City studied the black hole at the center of NCG 4051, a galaxy 35 million light-years away in the direction of the Big Dipper. The team determined that a wind of hot gas originates 8 billion miles away from the black hole—certainly farther away than the corner store, but still much closer than previously thought possible.

Although some matter can escape such a close encounter with a black hole, not much actually does. Krongold's group calculated that the wind blows away only between 2 and 5 percent of the material that orbits the black hole at any given time. That's too little to have much of a seeding effect outside the NCG 4051 galaxy. Bigger black holes in other galaxies, however, may yield different results. (*Astrophysical Journal*)

—Stéphane Reeb

Galaxy NCG 4051

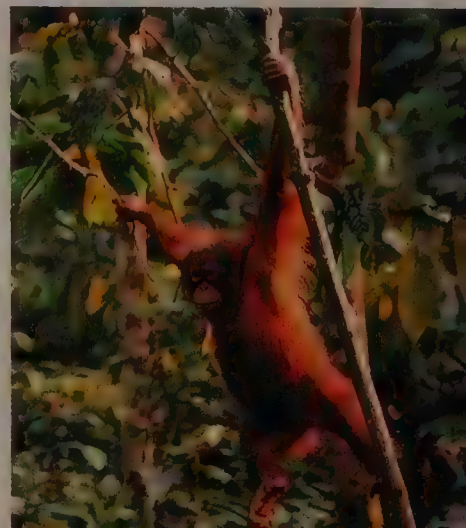
In the Swing of Things

Orangutans are the heaviest of all chiefly arboreal animals: males can weigh 200 pounds. But bulkiness can hinder a tree dweller, particularly when it has to cross from tree to tree; many branches are too thin and flexible to support an orangutan's weight.

Undaunted, the big apes have discovered another way to move through the canopy, one that puts their bulk to good use. The behavior is aptly called tree sway: an orangutan is heavy enough to oscillate a tree trunk until the arc of the tree's swing carries the animal over to a neighboring tree or vine.

Tree sway is certainly clever, but is it an energetically efficient means of locomotion? Susannah K.S. Thorpe, a primatologist at the University of Birmingham in Edgbaston, England, and two colleagues videotaped tree sway in Sumatra, Indonesia. By analyzing the tapes and accounting for various physical properties, including orangutan mass and tree-trunk stiffness, the investigators estimated that tree-swaying orangutans spend only half the energy they would if they jumped the gap. Furthermore, tree sway spends between ten and twenty-three times less energy than climbing down, ambling over to the next tree, and climbing back up.

Tree sway isn't the only way orangutans turn a tree's flexibility to their advantage. They, and certain other primates, have also been spotted using branches as catapults or springboards to propel themselves to destinations that would otherwise be just out of reach. (*Biology Letters*) —S.R.





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Phytoplankton to the Rescue?

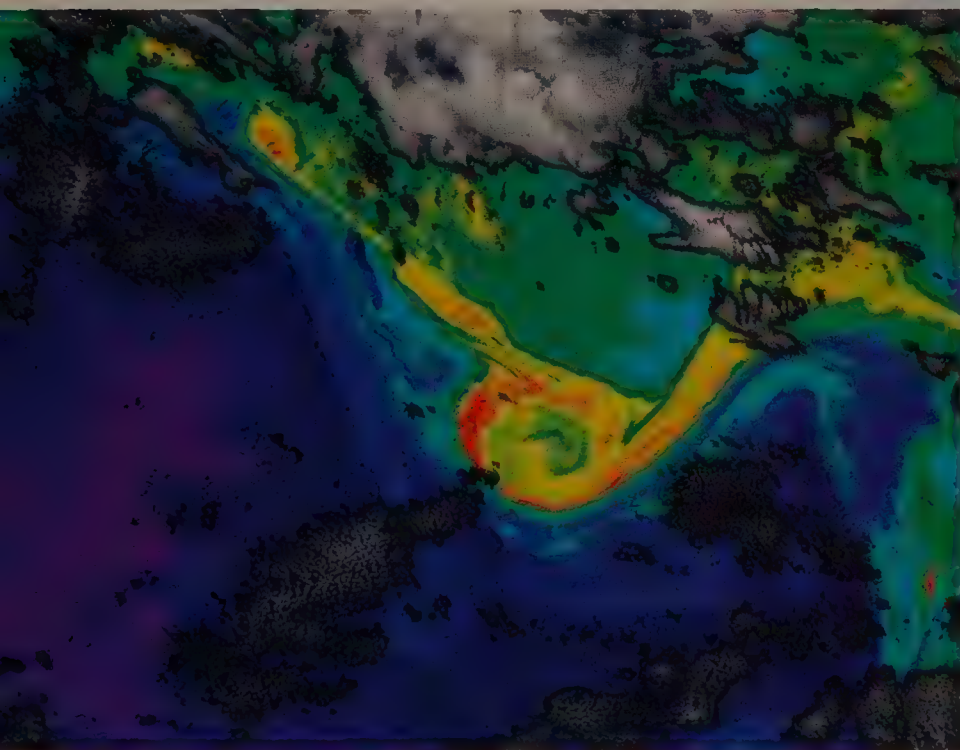
The Southern Ocean, surrounding Antarctica, is rich in nutrients, yet relatively little phytoplankton lives there. That's largely because the seawater is poor in dissolved iron, an element essential for phytoplankton growth. So some investigators have proposed fertilizing the Southern Ocean with iron to nourish larger populations of the microscopic algae. More phytoplankton, they have argued, would absorb more carbon dioxide through photosynthesis, ultimately storing tons of carbon deep in the ocean. There it could no longer contribute to global warming.

A recent study by Stéphane Blain of the University of the Mediterranean in Marseilles,

in the Southern Ocean. The bloom is a real whopper, lasting three months—a long time for a bloom—and covering more than 17,000 square miles of ocean, an area greater than twice the size of Massachusetts.

Blain confirms that the phenomenon is fueled by dissolved iron and other nutrients that well up from deeper waters. What's more, the amount of carbon taken out of circulation when some of the phytoplankton sinks to the ocean floor is surprisingly large: between ten and a hundred times more per unit of iron than had previously been estimated from small-scale experiments.

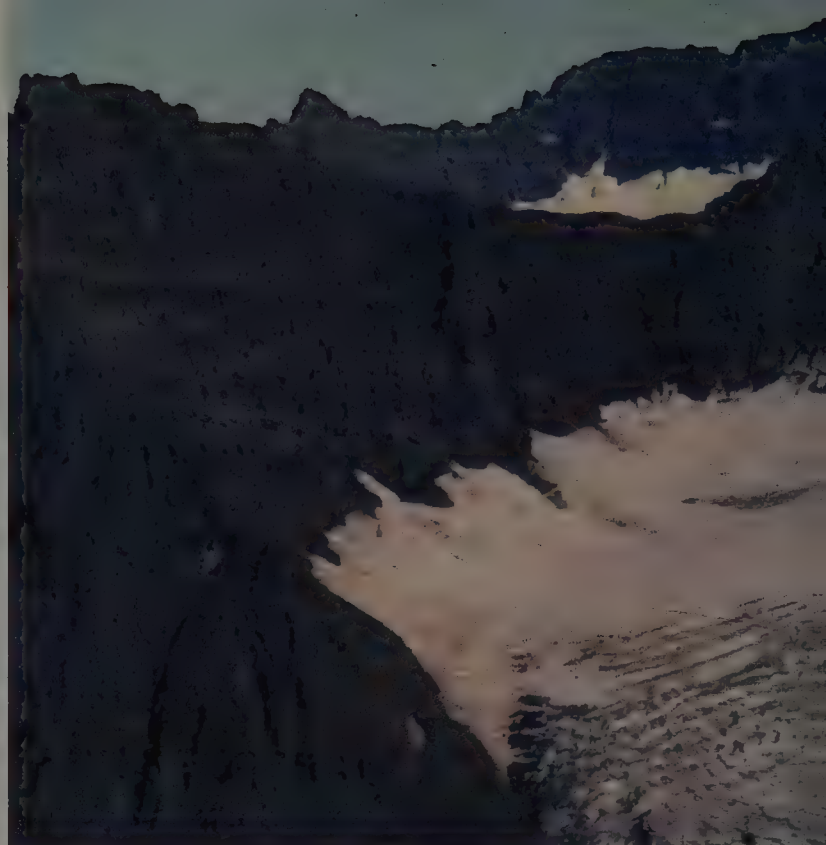
The oceanographers are quick to point out, however, that



Phytoplankton concentrations on the ocean surface are shown by colors that range from warm to cool in this false-color satellite image.

France, and a team of oceanographers sheds some light on the feasibility of that strategy. The team monitored the growth of a phytoplankton bloom near the Kerguelen Islands, which lie roughly equidistant from Africa, Antarctica, and Australia

artificial iron fertilization is unlikely to sequester carbon as effectively as does the deepwater iron around Kerguelen: it would be hard to replicate the slow and steady upwelling of iron and other nutrients in the region. (Nature) —S.R.



Basalt layers in eastern Greenland

Past Gas

People are to blame for much of today's climate change, but when the Earth warmed 55 million years ago, it wasn't our fault. At the time, a massive release of greenhouse gases caused global temperatures to rise more than nine Fahrenheit degrees and the oceans' acidity to increase sharply; numerous marine and terrestrial species went extinct. But what triggered the gas release has remained elusive, despite tantalizing clues that its onset might have coincided with volcanic activity so massive that what is now Greenland broke apart from Europe and the basin of the North Atlantic Ocean opened up.

Separate geologic records, however, hold traces of the two events: the temperature surge appears in North Atlantic marine sediments, and the massive volcanism appears in basalt layers of eastern Greenland. Now Michael Storey, a geochronologist at Roskilde University in Denmark, and two colleagues have pre-

cisely dated suspiciously similar ash layers that overlie both records. Sure enough, the layers were deposited at the same time, enabling Storey to sync the two records, and thereby to definitively link the ancient warming with the volcanic birth of the North Atlantic.

The new data strengthen a theory that magma from the volcanic activity heated marine sediments rich in organic matter, unleashing more than 1,500 billion tons of carbon into the atmosphere and oceans in the form of carbon dioxide or methane. Those greenhouse gases triggered the Paleocene-Eocene Thermal Maximum, as the ancient warm period is called.

Although the gases were released in just 20,000 years, it took more than 200,000 years for global temperatures to return to normal. Today, notes Storey, the burning of fossil fuels is releasing greenhouse gases at a much faster rate than did the Earth-shaping volcanism of eons ago. (Science)

—Corey Binns

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Working Group III Contribution to the Fourth Assessment Report of the IPCC

Fueling Our Future: An Introduction to Sustainable Energy

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Reveals extraordinary insight into how our reliance on fossil fuels can be changed over time so that we have a much more sustainable energy system in the near future.

Our Changing Planet

The View from Space

Editors:

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A unique and innovative look at the detrimental impact society has had on the environment throughout history, evidenced by one-of-a-kind NASA satellite images.

The Economics of Climate Change

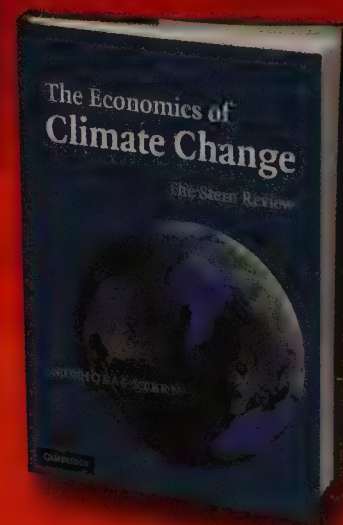
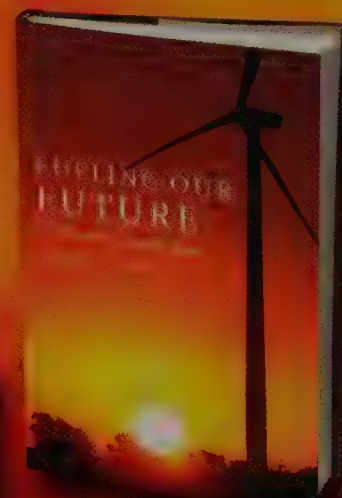
The Stern Review

Nicholas Stern

"...a vital step forward in securing an effective global policy on climate change...shows convincingly that the benefits of early global action to mitigate climate change will be far lower than the costs."

—Prof. Jeffrey D. Sachs,

Special Advisor to UN Secretary General Kofi Annan





Captive tuna

Neptune's Farms

Most of the terrestrial plants and animals farmed today were domesticated between 11,000 and 2,000 years ago; after that, domestication rates stagnated until the twentieth century. Yet since around 1900, according to a new analysis, domestication has skyrocketed, bringing more than 430 wild species into cultivation. If that number seems high, it's because almost all those species live out of sight—in the water. The domestication of algae, worms, mollusks, crustaceans, echinoderms, and of course fishes heralded the rise of aquaculture during the twentieth century.

Several such intriguing statistics were recently compiled by Carlos M. Duarte, a marine ecologist at the Mediterranean Institute for Advanced Studies in Majorca, Spain, and two coworkers. The investigators depict an industry poised to play a major role in meeting the world's rising demand for protein—yet one that, like agriculture, is potentially harmful to the environment and wild populations. Aquaculture production is growing at a rate of 7 to 8 percent a year. Some 106 aquatic species have been domesticated in the past decade alone. And about 250 marine and 180 freshwater animal species are now being "farmed," compared with just forty-four species of land animals.

The rise of aquaculture seems to have come none too soon, particularly because fisheries are ravenously depleting wild ocean stocks. Duarte notes, however, that for aquaculture to be sustainable, practitioners must reduce harmful side effects. Those include the overfishing of wild species to feed captive ones, the polluting of natural ecosystems with concentrated fish waste, and the potential for undesirable genetic mixing when farm escapees mate with wild stocks. (*Science*) —S.R.

Humongous Fungus (No Longer Among Us)

What's twenty feet tall and dines on detritus? *Prototaxites* fossils reminiscent of branchless tree trunks have been unearthed all over the world. In their day—between 420 million and 350 million years ago—they were by far the biggest things alive. But figuring out just what they were has long stumped paleontologists, who have variously suggested they might be coniferous plants or oversize algae, lichens, or fungi.

To nail down *Prototaxites*'s identity, C. Kevin Boyce, a paleobotanist at the University of Chicago, and several colleagues analyzed *Prototaxites* specimens from Canada and Maine to determine how much of the carbon in them is made

up of the isotope carbon-13 rather than carbon-12. The percentage of carbon-13 in an organism's tissues depends on its food. Photosynthesizers make their own food, of course, and distinct groups, depending on their method of photosynthesis, have characteristic levels of carbon-13.

Prototaxites, however, show no such consistency. Some specimens have carbon-13 levels similar to those of nearby, contemporaneous plants (some of them preserved as coal); others have much higher levels. Based on that variability, Boyce concludes that *Prototaxites* was not photosynthetic, but instead, like many modern fungi, fed on whatever dead organic matter

it encountered in the soil. The unbranched stems, he says, were probably robust, perennial reproductive structures that arose, as mushrooms do, from an extensive network of underground filaments. Indeed, the stems are made up of numerous funguslike filaments. So *Prototaxites*, it seems, was a fungus.

But why would a fungus grow so enormous? Boyce thinks *Prototaxites* got big simply because nothing that could deter it had yet evolved: no tall plants to crowd it, no herbivores to eat it, no large animals to knock it down. Unhindered, the ancient giants reached for the stars. (*Geology*)

—Rebecca Kessler

Talk Is Toxic

When your cell phone dies or succumbs to obsolescence, it probably follows the path of most other unwanted electronics: it becomes e-waste and heads for a landfill. After that, it's only a matter of time before its contents, which include toxic compounds and metals, leach into the soil. To date, about 700 million cell phones have been discarded or stashed away for later disposal in the United States alone.

Oladele A. Ogunseitan, an environmental health scientist, and his colleagues at the University of California, Irvine studied cell phones under one federal and two California protocols for assessing the hazardous content of e-waste. They shredded cast-off cell phones, soaked them in water at various levels of acidity, and analyzed what oozed out according to each protocol.

What did they find? High enough levels of lead to classify cell phones as hazardous waste under federal regulations. (Fortunately, manufacturers are phasing out lead-based solder, the main source of lead in cell phones.) Less expected were antimony, copper, nickel, and zinc—all known threats to human health—at high levels that exceeded the standards set by California, but not federal, regulations.

Those and other differences among the state and federal standards create problems for manufacturers and regulators, highlighting the need to review testing procedures. Even better would be for manufacturers to roll out less toxic electronic products. (*Environmental Science & Technology*)

—Graciela Flores



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A Human Cell in Sheep's Clothing

Biologists in Nevada are gambling that sheep can grow spare body parts for people.

By Olivia Judson

I'm about to see something odd. I'm about to see the creation of a sheep with a partly human liver.

I'm visiting the University of Nevada at its campus in Reno—a town with all the vice of Vegas but none of the charm. I've come to take part in a documentary about biotechnology. The star of the episode is in front of me on an operating table: a pregnant ewe, lying on her back with her legs splayed. She's been knocked out with an anesthetic, and the wool on her belly has been shaved off. Her skin is pink. The surgeon picks up a tool that looks like a sharp soldering iron and starts to make a cut down the belly. Acrid smoke rises from the cut.

I wrinkle my nose. "Strong smell of burning flesh," I say.

"Just smells of roast," says the surgeon.

Well, up to a point. But the burning seals the blood vessels shut, so there is no bleeding. None at all.

The surgeon cuts down the middle of the belly, in the gap where the stomach muscles meet. (If the sheep had a six-pack, the cut would be down the

center.) A few more cuts, and we have a window into the sheep's insides. The surgeon slides a hand into the opening and starts to haul out the womb. It's red, and glistens. I feel I'm watching clowns getting out of a clown car: the womb keeps coming and coming. I watch in astonishment. I had no idea you could partly pull out an animal's insides like this.

"A sheep's womb is a different shape from a human womb," says the surgeon. "A human womb looks like a sack. A sheep's womb has two horns that join at the base." She arranges the womb so that I can see both horns and starts running her hands over them, squeezing slightly. "The fetuses can be in either horn," she says. "Sometimes you have one in each, sometimes you have three in one and none in the other. This sheep has only one fetus. Here it is. The hips are here." The outlines of the fetal sheep, now almost nine weeks old and about six inches long, show through the lining of the womb; it's like looking at a child covered by a blanket.

"What happens now?"

"Now we inject human stem cells into the fetus. We don't need to cut into the womb, we just inject the human cells by pushing the needle through the wall of the womb and

into the body of the fetus.

This is very safe: we haven't lost a fetus since we started doing the operations this way" (they haven't lost any ewes either).

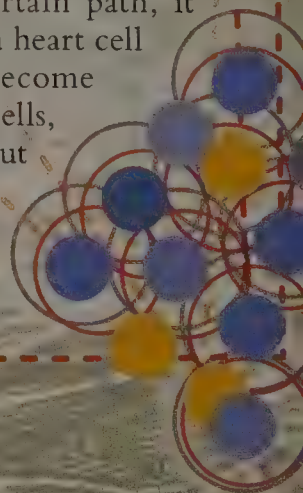
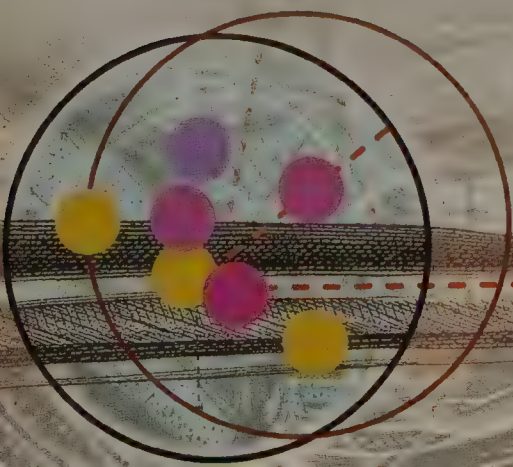
The surgeon's assistant picks up a long syringe filled with fluid.

"That contains the stem cells?" I ask.

"Yes. Stem cells from an adult," says the assistant. He positions the needle so that the fluid will be injected into the belly of the fetus, and pushes the plunger.

Each stem cell has the potential to become one of many kinds of tissue—which is why stem cells have become such a hot area of research. As stem cells differentiate into tissue of a particular type—heart, say—they switch off the genes they don't need for the heart and switch on the ones they do need. Thus a stem cell would take on such traits of a heart cell as shape and size. Once a cell has committed to a certain path, it loses its flexibility: a heart cell cannot suddenly become a liver cell. Stem cells, then, are cells without commitments.

Stem cells come from three main



sources. Embryos are one—they're the reason some of the work on stem cells is controversial. Many cells in an early embryo are stem cells, and they can form any kind of tissue. A second source is blood from the umbilical cords of newborn babies. And it turns out that adults also have a few stem cells, lurking in places such as bone marrow and skin. Stem cells from those sources are not quite as versatile as embryonic stem cells, but their use is uncontroversial. And it is a batch of human adult bone marrow stem cells that I've just seen injected. The surgeon stuffs the womb back into the sheep (somehow it all fits) and sews up the incision. The ewe is carried off to the recovery room. The operation has taken just fifteen minutes.

As for the fetus, "In another ninety days or so, it will be born," says the surgeon.

"And at that stage, part of its liver will be human?"

"Yes. The cells we injected will migrate through the fetus's body and settle into different

ent organs. Once the cells have settled in an organ, they start to divide. The cells around them tell them what tissue to become—so the human cells that arrive in the liver will become liver cells. Over time, as the cells keep dividing, you get clumps of human cells—so parts of the liver are purely human."

"Does that affect the sheep?"

"No. Although as much as 15 percent of the sheep may be cells of human origin, in all outward respects, these are normal sheep."

And indeed they are. On seeing some of them, I have no idea they are in any way remarkable. They are woolly, they say *baaa*, they look sheepish. Yet the more I think about it, the more remarkable they seem.

But first things first: why would anyone want to put human cells into a sheep?

The idea behind the research—which is the brainchild of Esmail D. Zanjani, a professor and chair of the university's department of animal biotechnology—is that one day, perhaps, livers grown this way could be transplanted into people.

At present there aren't enough organs available for transplant, so people in need often die while waiting for one. And even if you get the organ you need, your immune system may still reject it soon after the transplant—or years later.

The reason rejection happens is easy to understand. The immune system's job is to protect the body from intruders. Transplanted organs, unless

Continued on page 39



Cold Squirts

Antarctic scallops have lighter shells, less muscle mass, and more resilient hinge rubber than their tropical cousins.

By Adam Summers ~ Illustrations by Emily Damstra

Squids and octopuses are well known for their jet-propelled locomotion, scooting along by squirting water out of their mantles. But bivalves? Not many people have seen the ungainly, clapping flight of the scallop, but its motion is likewise jet-propelled.

The scallop is one of only a few bivalve mollusks—invertebrates with a two-part shell—that can truly swim. When threatened, the scallop claps the two halves of its shell together, and thus expels a jet of water that propels it to safety. By repeatedly slamming the shell, the scallop manages to wobble unsteadily through the water.

Simple enough, right? Yet it probably won't surprise regular readers of this column that basic research on the locomotion of scallops has implications for

scientific investigations of seemingly unrelated matters. It turns out that studying the swimming of cold-water scallops can guide applied research on manipulating polymers at various temperatures.

Like clams and mussels, scallops have two half shells, or "valves," attached to each other by a strong hinge. A large (and tasty) muscle, the adductor, is attached to the center of each valve, and when the muscle contracts, the shell closes to protect the animal's soft parts. The muscle can exert force only to close the shell; to open, the shell relies entirely on a little rubbery pad of protein just inside the hinge. The rubbery pad gets squashed when the shell closes, but as the closing muscle relaxes, the pad rebounds and pushes the shell back open. That's why when you're shopping for live bivalves for dinner, you want the closed ones: they are manifestly alive because they're still holding their shells tightly shut.

The jetting mechanism in a scallop works like a somewhat inefficient two-cycle engine. When the adductor muscle closes the shell, water squirts out; when the adductor relaxes, the rubbery pad pops the shell back open, allowing water back inside and replenishing the jet [see illustration across these two pages]. The cycles repeat until the scallop is out of predator range or closer to a better food supply. Unfortunately, the jet-power phase is delivered for only a short part of the cycle. Scallops, however, have adapted to make the most of what power and thrust they can produce.

One of their tricks is to lighten the load by having thin shells, whose weakness is offset by corrugations. Another adaptation—the key, in fact, to their culinary charm—is that large, tasty adductor muscle, physiologically suited to the powerful cycles of contraction and relaxation in jetting. Finally, that little rubbery pad is made of a natural elastic called abductin, which does an excellent job of returning the energy put into it by shell closure.

As inefficient as jetting is for all scallops, the cold-water species face even tougher challenges. For one thing, the power output of muscles decreases in the cold. For another, cold water is more viscous, and offers more resistance. And finally, in the Antarctic, where the water temperature is only



twenty-eight degrees Fahrenheit, the rubbery abductin should become less elastic. Those factors explain why the Antarctic scallop, *Adamussium colbecki*, is just barely able to sustain level motion.

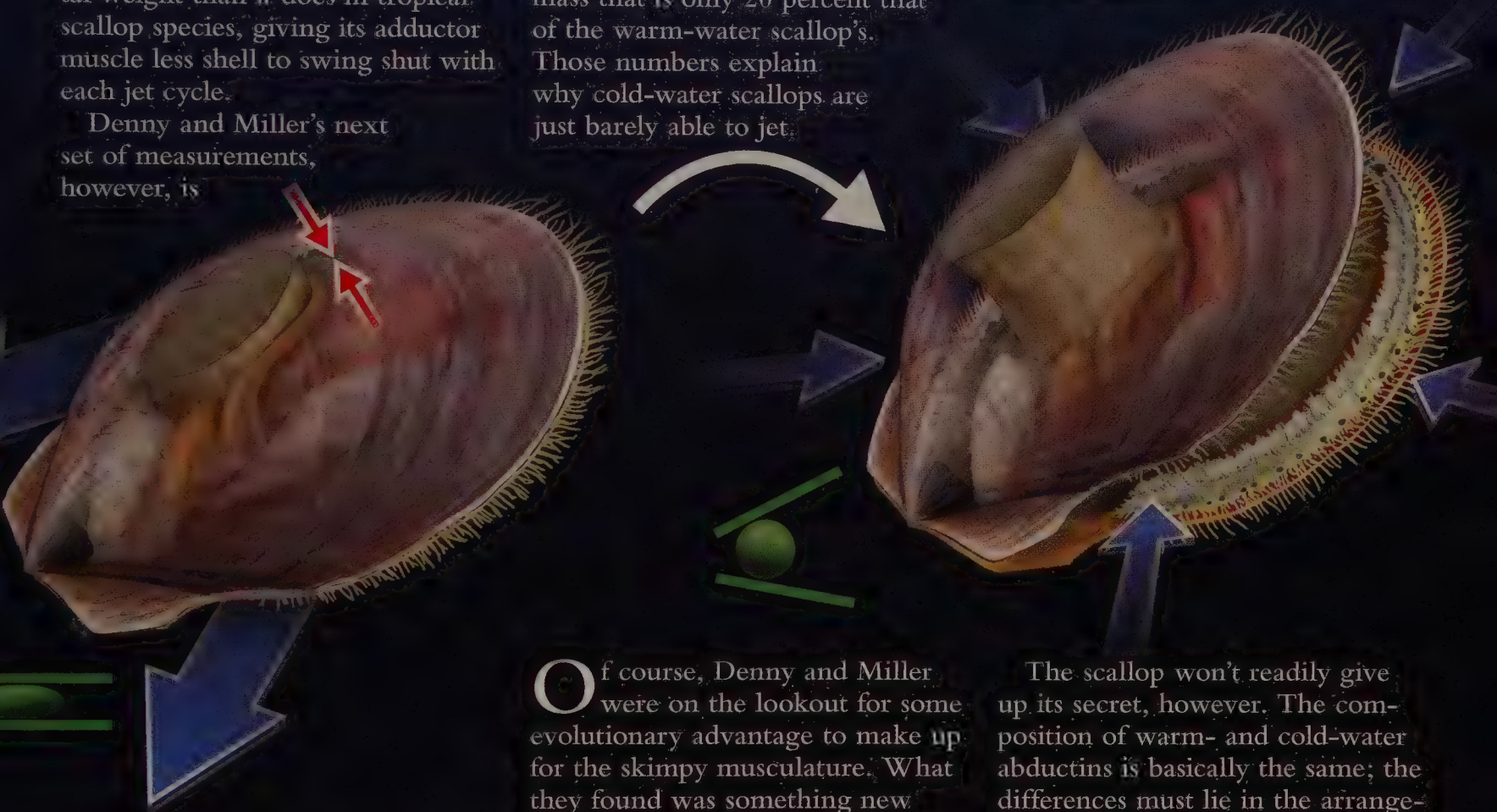
Yet despite the cold, *A. colbecki* manages to swim. Mark W. Denny and Luke P. Miller, biomechanists at Stanford's Hopkins Marine Station in Pacific Grove, California, traveled all the way south to McMurdo Sound to figure out how. Their initial findings were not unexpected: in *A. colbecki* the shell contributes less to the animal's total weight than it does in tropical scallop species, giving its adductor muscle less shell to swing shut with each jet cycle.

Denny and Miller's next set of measurements, however, is

harder to understand. Instead of an extra-large muscle to compensate for the cold, they found that *A. colbecki* has a closing adductor half as big as the adductor in a warm-water bivalve of similar size. Although that, too, saves weight, the shift in proportions implies that closing the shell takes less force but more time—not to mention that it takes more cold-water scallops to make a satisfying entrée. In fact, the combination of low shell mass and low muscle mass translates into a severe handicap for the scallop—a ratio of jetting power to animal mass that is only 20 percent that of the warm-water scallop's. Those numbers explain why cold-water scallops are just barely able to jet.

the Antarctic scallop's abductin, they did indeed find a decrease in bounce with a drop in temperature, but it was a smaller decrease than occurs in temperate-zone mollusks. Natural selection has thus fine-tuned the response of abductin to temperature.

The difference is small potatoes for the scallop; the energy returned by Antarctic abductin is only a small fraction of the total needed to jet. But a rubber that retains its bounce in the cold would make materials scientists take notice.



Antarctic scallop escapes capture by jet propulsion. The creature launches itself by closing the two halves of its shell with its adductor muscle. The closing action forces water out of the shell's interior and compresses the rubbery hinge tissue (green). As the hinge tissue rebounds, the shell slowly opens, water re-enters the shell, and the muscle returns to its initial position, ready for another thrust.

Blue arrow: Movement of water
Red arrow: Force of adductor muscle

Of course, Denny and Miller were on the lookout for some evolutionary advantage to make up for the skimpy musculature. What they found was something new about the properties of polymers.

In severe cold, the abductin in the scallop's hinge should become less able to store energy. After all, as many readers may recall, the catastrophic explosion of the space shuttle *Challenger* in 1986 was caused by cold weather, which made the booster-rocket O-rings so hard and brittle that they allowed hot gases to escape. When Denny and Miller checked the effect of changing temperature on

The scallop won't readily give up its secret, however. The composition of warm- and cold-water abductins is basically the same; the differences must lie in the arrangement of the protein polymers that store and release energy. Identifying those minute differences will further confirm the rule of thumb that blue-sky (or in this case blue-water) research has unanticipated implications far outside the shell of the original work.

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Space, Time, and Timbuktu

The legendary city on the Sahara's southern fringe can look back on a history of commercial, intellectual, and religious wealth. Today as in the past, however, political power eludes it.

By Marq de Villiers and Sheila Hirtle

The Well of Bukt, so-called, is a paltry thing, about three feet across and not much deeper, and contains no water at all. A goat-skin bag hangs over the opening, suspended from three slender wooden poles poked into the ground, a show-and-tell of how the water was drawn to the surface in those days when there was water, if there ever was any. The whole thing is set up in a sandy courtyard that serves as a kind of anteroom to the municipal museum of Timbuktu.

An old man, wizened and sly, was sitting on a bench in the shade, smoking up a storm. He'd have sold us a postcard or even a goatskin bag if we had wanted one, but he didn't try very hard.

"Is this really the well of Bukt?" we asked.

He hesitated, assessing our credulity, then grinned. "It is a well of the same type," he said at last. "No one knows where the real well was, but there must have been one. Who is to say it wasn't here?"

Who indeed? A Well of Bukt, or Tin Bukt, is part of the founding myth of Timbuktu, a thousand-

year-old settlement on the southern border of the Sahara Desert. Although now it is a peripheral city of 30,000 in the modern state of Mali, its name evokes, for those familiar with its history, a luminous past as a crossroads of caravan routes and of learning, and still holds, for jaded Western tourists, the promise of a remote and exotic destination. Its name may even be a guide to fact, when fact is lost in the mists of unrecorded time. The most common version of the story of the city's origin goes like this:

Timbuktu was founded by a group of Tuareg herdsmen around the start of the eleventh century. This particular group's range was the desert between the Niger River and the oasis town of Arawan, about a week's journey north of the river. In the wet season (such as it is in the desert), they would linger in the north. In the dry season, the summer, they would bring their herds closer to the Niger to graze. They set up a camp in the dunes at a convenient spot a half-dozen miles from the river, where they dug a well. *Tin* means either "well" or merely "place" in



Aerial view of Timbuktu, top, looking northward toward the Sahara, shows a city of 30,000 people who live mostly in single-story mud buildings spread across about four square miles of desert. Strategically positioned near the Niger River, the city owed its rise to trade in gold and slaves, manufactured goods from the Mediterranean, and salt from the desert itself. Above: a market in the city today.

the Tuareg language, Tamashek—a member of the Berber family of languages. After a few years that convenient camp became more permanent, and the nomads would leave their goods there in the charge of an old woman named Buktu. Accordingly, the

Tuareg herders would refer to returning to Tin Buktu, “the place of Buktu.”

Well, as a story it’s tidy enough, though some traditions say *buktu* isn’t a person’s name at all, but means “woman with a large navel” in the language of the Songhai, an unrelated ethnic group centered downriver from Timbuktu. Others suggest that the woman referred to as Buktu was not a Tuareg at all, but a native Songhai. In a further refinement, the word is also translated as “woman with a large lump,” which is then taken to mean navel (no doubt one of the earliest references to an “outie” in literature). All such romantic notions were scorned by the nineteenth-century German explorer and linguist Heinrich Barth, who pointed out that the Songhai word for navel also means a shallow depression between sand dunes, and that in origin the city’s name, Timbuktu, most probably means nothing more than “the place between dunes.”

Whatever the legends may say, most historians agree that the Tuareg are descendants of Berber groups that were driven from the Mediterranean plains of northern Africa by various invasions and conquests. One way or another, the nomads made the desert their home and founded Timbuktu in the eleventh century. Their camp gradually became an important gateway to the Sahara. Traders began showing up from the river and points farther south, accumulating goods for a venture across the desert itself.

The Tuareg did not hold sway over the city for long, however. Over the centuries Timbuktu has been owned by a succession of foreign emperors, kings, and sultans. From time to time the Tuareg have descended on the city to take it for a decade or two, or merely to loot and pillage before retreating to the desert again. Theirs has not been an altogether happy history. They’re a proud and even arrogant culture, but their present status is uncertain and their future bleak. Rather like Timbuktu’s.

Arawan lies some 180 miles almost due north of Timbuktu, a six days’ slog on foot and camel. It is the last real town—with the last wells—on the way to the historic salt mines of Taoudenni and Taghaza, more than 200 and 300 miles farther on. From



the thirteenth century until well into the seventeenth, that salt was quarried by slaves and carried in great blocks by camel to Timbuktu in exchange for gold. Modern salt gatherers from Timbuktu still use Arawan as a way station to Taoudenni (Taghaza is now abandoned). In its heyday, however, Arawan had 3,000 inhabitants and 170 productive wells; today, with the dunes rolling relentlessly in, it has only a handful of residents and two wells.

Arawan was also a way station for caravans headed still farther north across the desert. They would continue on to Taoudenni or Taghaza, or both, to water their camels and rest. Ahead they faced a desert that flattened into monotonous stony plains, with not even a dune or a ridge or a boulder as relief. Still, convoys of as many as 10,000 camels streamed across those reaches, carrying gold and slaves to the towns north of the Sahara, and bringing back manufactured goods from the Mediterranean along with salt from the desert itself [see map above].

The major sources of gold were to the south, in modern Ghana, Guinea, and Senegal. To the east, on the Niger River, was Gao, capital of the Songhai empire, considered one of the three greatest empires that arose in West Africa. While the empire flourished, from 1464 until about 1600, its kings ruled over Timbuktu. Beyond Gao, caravans from Timbuktu reached other peoples and centers, connecting via the Nile with Egypt and ultimately with the caliphs of Baghdad and the holy places of Mecca and Medina.

Nowadays, from Timbuktu west to the Atlantic it is all desert. Along the way the traveler passes

Walata, once a rival to Timbuktu but now much decayed, and the ruins of many far older cities. Among them is Koumbi Saleh, in what is now southeastern Mauritania. It was the capital of the Ghana-Wagadu empire, considered the first great empire of West Africa, which flourished ca. 300 B.C. until A.D. 1100. Today all one sees of the city is crumbling rubble. Also remarkable are the thousands of slag deposits from the smelting of iron ore that have been found on the north bank of the Niger. The area now has no forests for fuel. Southwest, upriver on the Niger, one encounters the city of Mopti, as old as Timbuktu, and the more ancient city of Djenné. Farther on is the heartland of the second of the great West African empires, which prevailed from 1235 until ca. 1500. That was Mali, for which the modern state is named, but the precise location of its capital, Niani, is unknown.

Caravan routes once led north across the desert from Koumbi Saleh and other early centers, as did the later routes from Timbuktu. Why those earlier routes fell into disuse and why the cities crumbled is one of the fascinating puzzles of African archaeology. It may have been a combination of ecological collapse, desertification (partly human-caused), and the turmoil of warfare and religious strife. Known climate changes in the southern Sahara provide important clues. Most of the abandonment of settlements took place during a dry phase from 1100 until 1500. The founding of Timbuktu also corresponds with the start of that phase, and may explain why the nomads showed up where they did at the Niger River.

Timbuktu itself is not short of water. Its municipal wells maintain their steady flow from aquifers deep below the surface: fossil waters left over from more verdant times, still being recharged by the Niger. Yet the city's immediate neighborhood is changing, the dunes edging ever closer.

Shindouk Mohamed Lamine Ould Najim [see his photograph on the cover of this issue] is the chief of a small tribe of Bérabiche whose desert camp is near Arawan. He has a house in Timbuktu, but spends much of his time in the desert. He makes his living operating camel caravans and as a guide, steering not only individual parties, but also movie crews, survey expeditions, prospectors, and adventurers through some of the most difficult terrain on earth. Shindouk comes from a long and illustrious line of desert experts, which is what his business card calls him: *guide de Tombouctou, expert du désert*.

Shindouk's father, Najim, was one of the most famous Saharan guides of them all. Tales of his exploits are legion. Once he even helped save a lost convoy at long distance, by radio. The convoy's

guides had become confused and disoriented. With only a few quarts of water remaining, they managed to get Timbuktu on the radio to ask for help. Someone called for Najim. When he came to the military post where the transmitter was, he asked to speak to the most senior guide present.

"Describe the place," he demanded. "What does it look like, the horizon? What is its shape to the west and the north, to the south and the east? Are there any hills? Are there dunes, and what size and shape? Is the ground stony?"

The guide did as he was asked.

"Pick up some sand," said Najim. "Tell me its color: is it clear, with white grains, or dark, with black particles? And its feel. How big are the grains? Is it sharp to the fingers?"

The guide obeyed once again.

Najim sifted the descriptions in his mind. Then he said, "You describe a small mountain ahead of you, to the north. Go there, turn west when you get there, travel for half an hour, and call me again."

Three hours later the convoy reached the mountain and turned left as instructed. Najim came back on the radiophone.

"Do you see a large free-standing rock off to your left?" he asked.

"We do."

"Get the men to push it over. There is water beneath it."

On another occasion, a military convoy had been trying to map the boundary with Algeria. The military frequently employed civilian freelance guides, who sometimes felt exploited and underpaid. Najim had taken this convoy deep into the desert, and one day, he stopped. "I feel dizzy," he said. "I can't even tell where the west is, or where the north. I don't know what to do."

The convoy leaders began to panic. "What can we do?" they asked.

"Two things might help," Najim replied. "More money, and an honorary commission in the Army."

An urgent phone call to Timbuktu military headquarters got patched through to Bamako, the capital, and a short time later the president of the republic himself called to personally award Najim his officer's commission. He also got more money. The mapping survey continued amicably.

In the past, the caravans coming in from the deep desert would have been met by a commercial agent and escorted into town. Then the tallest structure in Timbuktu would not have been the water tower one sees today, but the minaret of the Sankoré mosque, already more than a hundred

years old when Timbuktu was occupied by the forces of the Mali emperor Musa, in the middle 1300s. That event heralded the start of Timbuktu's first golden age, and its first great expansion as the main entrepôt for the southern Sahara and a haven



Minaret of the Sankoré mosque, built of mud plaster, is pierced with beams that serve as scaffolding when renovations must be done. Much of the present construction dates to the nineteenth century, but the mosque was established in the late 1100s.

for scholars of Islam. The city's second and most significant golden age came several centuries later, under the rule of the kings of Gao.

Then as now, Timbuktu was made largely of mud. The mosques are still mainly mud, as are the tombs and shrines. The central town is a maze of narrow alleyways punctuated by secretive doorways, some providing a glimpse of courtyards, and glassless windows with intricately carved screens of wood. At intervals are ruined buildings and vacant lots

that look like bomb sites, but the only bomb that has dropped is time. A shrinking population has no money to repair a city made of mud, in which the buildings melt in the wet-season rains unless protected by fresh plaster.

We paid a visit to Abdel Kader Haïdara, whose home sprawls off one of the unnamed sandy alleys in the southeast quadrant of the city. The windowless main living room was sheltered from the sun, turquoise and cool, with carpets on the floor and red plush banquettes. The walls were lined with bookcases and cabinets and a hulking television set. After the first pleasantries, our conversation ranged from the legends about the founding of Timbuktu, through the golden age of the city, to its gradual decline after the Moroccan invasions some 400 years ago.

Eventually we fell to discussing Ahmed Baba, a scholar who died in the early 1600s but whose name is often still mentioned as though he were a favorite uncle who has just popped out for a quick prayer. Ahmed Baba's personal library included some 1,600 volumes when he died, but he had often remarked that his was one of the lesser collections. We knew that our host was himself the head of the family that owned the Mamma Haïdara Library, one of the largest extant collections of ancient manuscripts left in the region, a priceless link to the glorious past.

Could we see it?

We could, indeed. The building that housed it was undergoing much-needed and expensive renovations, so Haïdara had, well, brought a good deal of it home. Where better to keep an eye on it? It was his, after all. Our host led us back into the outer courtyard. In one wall was a battered corrugated-iron door, locked with an old-fashioned padlock. Haïdara fished a bunch of keys from his robe and opened the door, pushing it inward with a grinding sound. Inside the small room we saw tottering piles of ancient manuscripts, some in loose bundles, some in battered tin trunks or leather portfolios, others simply heaped on the dusty floor.

Buried in those floor-to-ceiling stacks were all the great themes of Timbuktu's history, the very

reasons it exerted such an hypnotic attraction on the Mediterranean world: its flowering, from a pasturing place for Tuareg nomads into a trading emporium that prospered on gold and salt and slaves; its reputation for wealth, which loomed so large it attracted the attention of the Venetian traders and then of the sultan of Morocco Ahmad al-Mansur, who wanted the gold traffic for himself to further his ambition to supplant the Caliphs of Baghdad; and its preeminence as a center of learning, of Islamic scholarship, luring the learned and the pious from Alexandria, Baghdad, Cordoba, Fez, Marrakech, Mecca, Tlemcen, Tripoli.

Intellectual wealth, religious piety, and commercial wealth are intertwined all through the city's history. Only political wealth is missing. Many powerful sovereigns wanted to control Timbuktu, and sometimes they did; but it never became the capital of anything. It was the outlying commercial emporium first of the Mali kings, governing from the southwest,

then the rulers of Songhai, governing from the east, then the sultans of Morocco, governing from the north, across the sand seas. In between it was governed, mostly ineptly and fiercely, by various occupiers—the Bambara, now Mali's majority ethnic group; the nomadic Fulani, a cattle-herding people; and the Tuareg themselves. But it never ran its own affairs.

Political power still eludes it. After fifty years of independence, the Malian state has yet to build a highway from the capital, Bamako, to Timbuktu. Timbuktu is a northern town, a Tuareg town, a frontier town. No one in the capital cares. □

*This article was adapted from the forthcoming book by Marq de Villiers and Sheila Hirtle, *Timbuktu: The Sahara's Fabled City of Gold*, which is being published in August by Walker & Co. Copyright © 2007 by Walker & Co.*



Old manuscript recalls Timbuktu's reputation as a center of learning and Islamic scholarship, which at its height, from the 1300s until about 1600, attracted scholars from across North Africa and the Middle East.

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How Now, Little Cow?

The vaquita, the world's smallest porpoise, lives only in the northern Gulf of California. It often drowns in fishing nets as bycatch, and just 200 individuals remain. Can the species survive?

By Robert L. Pitman and Lorenzo Rojas-Bracho

Vaquita mother and her calf, as portrayed by an artist, embody whatever hope remains for the survival of the species. The population of the diminutive porpoises continues to fall, in part because they are slow to mature and have a low birthrate. Those factors merely compound the effect of their high mortality from entanglement in fishing gear—the main cause of their alarming decline.





Vaquita

Two on-duty and three dozing off-duty observers spring to attention on the flying bridge of our research vessel under the suffocating heat of the Mexican sun. The shouting observer checks the readings on her binoculars, but she can barely check her excitement: "Twenty-two degrees left of the bow, about 1,200 meters away. Looks like a mother and calf swimming together!"

Momentary mayhem breaks out on the flying bridge as members of the survey team tussle for binoculars and jockey for position. Everyone wants to see the world's most endangered marine mammal.

We have been looking for vaquitas for more than a week with little success, here in the northern reaches of the Gulf of California, Mexico. The gulf, also called the Sea of Cortez, is the thousand-mile-long spear of ocean wedged between the mainland of northwestern Mexico and Baja California. There is no wind: the ocean's surface looks like stretched Saran Wrap. The air temperature climbed above 100 degrees Fahrenheit just after sunrise this morning and hasn't looked back. Onshore, all we can see is desert. Towering cardon cactuses stand like sentinels flexing their biceps; the rest of the vegetation is mainly scrubby afterthought, sparsely sprinkled over scorching sand. This is the last place on Earth you would expect to see a porpoise, and our survey team is well aware that the vaquita, the desert porpoise, may not be here for anyone to see much longer.

But the austerity surrounding the gulf belies the productivity just beneath its surface. Seasonal winds and a thirty-foot tidal range dredge up cool, nutrient-rich waters that support an enormously productive marine food chain.

The gulf is home to large populations of blue whales, fin whales, and sperm whales; throngs of common dolphins charge about in schools that number in the thousands; multitudes of breeding seabirds crowd together on cactus-studded islets. The stark contrast between the relatively barren terrestrial landscape and the lush marine seascape is a defining paradox evident everywhere in the gulf.

Tucked away in the northernmost extremity of that abundant ecosystem lives the entire world population of the vaquita—a cetacean, as are whales, dolphins, and the five other living species of porpoise. (Porpoises are distinguished from dolphins in having teeth that are flat, like chisels, instead of round, like pegs.) The vaquita was first recognized as a new species in 1958, on the basis of three skulls found on beaches in the northern gulf. But a quarter century passed before a live animal was scientifically documented, and only in 1985 were its external features first described by biologists.

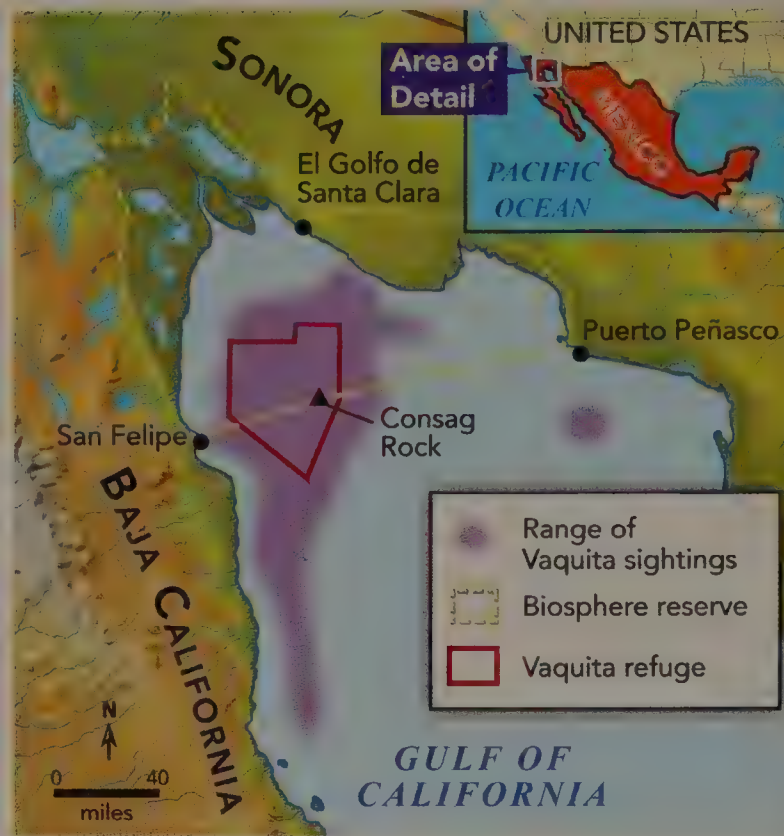
In addition to being the rarest of cetaceans, the vaquita is also the smallest. Its torpedo-shaped body measures less than five feet from snout to tail; calves are just twenty-eight inches long at birth, the size of a large loaf of bread. From a distance, the vaquita appears drab gray with a lighter belly, but at close range some intriguing details in the paint job emerge. A black stripe runs forward from each flipper to the middle of the lower lip, so the animal appears to be holding its own bridle. It has a black, circular patch around each eye. And its black lips set off a haunting little smile; Mona Lisa with black lipstick.

But the vaquita has no reason to smile. The world population of vaquitas is probably about 200 individuals—you can see more people

in a Wal-Mart on a busy weekend. And though Wal-Martians are definitely in no danger of extinction, the vaquita is losing market share. Gill nets—nearly invisible fishing nets set in the water like curtains and often left unattended—are the single greatest cause of vaquita mortality each year. Vaquitas become entangled and drown when they swim into the nets by accident; or they might be lured there by fish that are already

stuck. Vaquitas aren't the intended targets of any fishery; they're merely the bycatch of local fishermen trying to earn a living—collateral damage.

With the vaquita's population in steady decline, its distribution in the northern gulf has also contracted, so that its range is now the smallest of any marine mammal. Nearly the entire population lives in a region less than forty miles across. To put that into perspective, while on surveys throughout the gulf, we have seen a few dozen vaquitas over the years. But never have we seen one without being able to look up and see Consag Rock, a 300-foot-tall, guano-covered spire in the middle of the northern gulf.



Even the vaquita's scientific name, *Phocoena sinus*, acknowledges its claustrophobic range. *Phocoena* is derived from both the Greek and Latin words for "porpoise"; *sinus* is Latin for "bay" or "pocket," and refers to the animal's restricted home waters. (The common name, *vaquita*, means "little cow" in Spanish—a rather fitting name now that biologists know that all cetaceans are the product of a successful re-invasion of the ocean by terrestrial ungulates.)

At a recent forum convened in San Diego to address the fate of the vanishing vaquita, the organizers displayed a gallery of nearly every known photograph of the species. Most showed a dead animal swaddled in gill net in the bottom of a fishing boat, that innocent smile frozen on its face in death as in life. There were only a couple of photographs of live animals, and they were no more than blurred images of a head or a dorsal fin hastily rolling out of sight in the distance. We were struck that a large mammal living in our time could be driven off the planet forever, and leave behind such a scant record that it was ever here.



Snapshots of dead animals, such as this young vaquita brought to shore after drowning in a fishing net, comprise almost the entire photographic record of the species. Few living vaquitas have been captured with a camera.

The best estimate of the world's vaquita population to date comes from a 1997 shipboard survey of the vaquita's known range, which was conducted by the U.S. National Marine Fisheries Service in collaboration with Mexican investigators. From the survey data, Armando Jaramillo-Legorreta, a Ph.D. candidate in oceanography at the Autonomous University of Baja California in Ensenada, and several of his colleagues estimated the vaquita population at 567 individuals.

To determine whether the population is growing, declining, or holding steady, one must know, among other things, its mortality from both natural and human causes. The latter is essentially the number of animals that die in nets every year, and that critical piece of information was supplied by Caterina D'Agrosa, now a postdoctoral fellow at Arizona State University in Tempe. Between January 1993 and January 1995, as part of her master's thesis, D'Agrosa had interviewed fishermen and

placed observers aboard fishing boats, primarily in El Golfo de Santa Clara, one of the three main fishing communities in the northern gulf. Extrapolating from her sample, she estimated that seventy-eight vaquitas were being killed annually, an overall population decline of about 10 percent per year. At that rate, a population of 567 individuals in 1997 would have plummeted to about 200 by now.

Beyond those population estimates, and despite numerous surveys to observe vaquitas in the wild, little is known about their biology or life history. Because the animal is shy as well as rare, it has not readily disclosed its secrets. But what little is known does not bode well for its future. The normal lifespan is probably twenty years or more. It reaches sexual maturity between three and six years of age, and females apparently give birth to a single calf every other year. It typically travels alone or in mother-and-calf pairs. A recent study determined that the species has little or no genetic diversity; it may have passed through a population bottleneck at some time in its past, or evolved from a small founder population. The combination of low numbers, late maturity, low birth rate, and low genetic diversity makes the vaquita vulnerable to extinction, even without such strong pressure from people.

In 1993, as a result of public and scientific outcry about its fate, the Mexican government created the Upper Gulf of California and Colorado River Delta Biosphere Reserve [see map on opposite page]. Within the reserve, gill nets are prohibited. At the time, the reserve was thought to include most of the vaquita's marine habitat, but after two shipboard surveys, in 1993 and 1997, it became clear that as much as half of the population was actually living south of the reserve boundary. Consequently, in December 2005 the Mexican government designated a vaquita refuge, which overlaps part of the biosphere reserve and includes an area where some 80 percent of recent vaquita sightings have been made.

In spite of the good intentions reflected by the creation of those protected areas, harmful fishing practices have continued virtually unchecked. A 2006 review concluded that there has been little or no change either inside or outside the biosphere reserve since its creation. When we visited the vaquita refuge in March 2006, we found unattended gill nets set right in the middle of it. One of us (Rojas-Bracho) recently launched a series of aerial surveys, which will provide a far better appraisal of fishing activity throughout the region than has so far been possible. But because the boundaries of the reserve and the refuge are not marked, and because there is little enforcement of the no-gill-netting rule, poor results

seem all but inevitable.

Fishermen, armed with nets, are the main reason for the vaquita's decline—just as they are for the mortality of marine mammals everywhere else in the world. Of the six porpoise species, for instance, the two that live in open oceans—and thus have the least exposure to gill nets—are faring much better than their shallow-water relatives. Populations of Dall's porpoise (*Phocoenoides dalli*) in the North Pacific and the spectacled porpoise (*Phocoena dioptrica*) in the Southern Ocean are in relatively good shape.

For the rest, the story is quite the contrary. On the Yangtze River in China, an endemic population of finless porpoise (*Neophocoena phocoenoides*), the world's only freshwater porpoise population, is in steep decline. The causes? Unmanaged fishing and rampant development on the river. The marine populations of finless porpoise are somewhat better off, depending on how much fishing is done in their home waters. The message is clear: if there's a net in the water, a porpoise will find it.

And then there's the baiji (*Lipotes vexillifer*), a dolphin that lived only in the Yangtze River. In the fall of 2006 one of us (Pitman) took part in a search for the last baiji. For the past twenty to thirty years the baiji had been recognized as the world's most critically endangered cetacean, because of its high rate of accidental drownings in fishing gear. In a six-week survey, the searchers failed to find a single individual—and in the end, were forced to conclude that the baiji, after more than 20 million years swimming in the Yangtze, was probably extinct.

There are troubling similarities between the



Consag Rock, in the northern Gulf of California, lies at the heart of the vaquita's range. In fact, the authors have never sighted a vaquita when they couldn't also see Consag Rock.

*For the vaquita the trend is clear, the threats are known,
and the answer is simple: the nets must come out of the water.*

baiji and the vaquita, the next cetacean in line for extinction. Historically, both species occupied small, insular ranges surrounded by fishing communities. They both faced the same threat to survival: nets. Both species, like all cetaceans, were slow to mature and had long intervals between births, so even if the threats to their survival had been removed, their reduced populations would have recovered very slowly. Both had been at risk of extinction for some time. "Protective measures" were put in place for both: reserves were created and laws were crafted that made harmful fishing practices illegal in protected areas. But the reserves existed largely in name only, and enforcement was unsuccessful.

All that remains of the baiji are lessons. Extinction is real. Unmanaged fishing practices have the potential not just to reduce populations of aquatic mammals, but to catch and kill every last member of a species. And extinction can happen quickly, right before our eyes. A scientific paper published a few months before the Yangtze River survey concluded that the baiji would be extinct in twenty years if protective measures were not stepped up. But the last baiji had probably already died before that article was written.

Vaquita conservation, of course, raises thorny ethical and sociological issues. The people who live along the desert shores eke out a tenuous living by fishing in the same waters as the vaquita. They simply want to keep their families fed and improve their lot. The tragedy is that their poverty and their struggles will continue long after the last vaquita loses its own final struggle in a ball of monofilament net.

It is all too easy to imagine the end of the vaquita: An exasperated fisherman wrestles with an entangled carcass under the blazing Mexican sun. He finally extricates it from the net and dumps it unceremoniously over the side of his *panga*—his small, open fishing boat. As the last vaquita sinks out of sight, the last human being ever to see one goes back to pulling his net.

We need to take care of this fisherman if we want to take care of the vaquita.

As in the baiji's case, the future of the vaquita is no longer a scientific issue. The time for surveys is over. The trend is clear, the threats are known, and the answer is simple: the nets must come out of the water. A recent socioeconomic survey of the northern gulf suggested that for about \$25 million, all vaquita bycatch could be eliminated. The

money would be directed toward the 3,000 or so fishermen who make their living putting nets into those waters, either to buy out their fishing gear and help them get into another line of work, or to teach them sustainable fishing practices that don't threaten the vaquita. Economists from the U.S. and Mexico are now working to design such a program, but the money remains a stumbling block.

Maybe what the vaquita needs is a corporate sponsor. For the price of a couple of minutes of ad time during the Super Bowl, an underwriter could buy a future for the species. Corporate donations do not come free, of course—vaquitas might have to carry painted logos on their sides, like NASCAR race cars. Perhaps the species could be renamed, something like "The Home Depot 'You can do it, we can help' porpoise." Increasingly, people seem to be losing the ability to recognize the intrinsic value of Earth's wildlife; species will have to earn their way to justify their survival, a sad but honest appraisal of a world losing contact with its natural heritage and hewing only to market forces.

Just so, if this little porpoise goes extinct, many people will shrug off its passing as the disappearance of an obscure species from an out-of-the-way corner of the globe: "So what?" For others, however, the loss of any biological diversity on our planet is of grievous concern, particularly when what is lost is a relatively large, warm-blooded creature like the vaquita.

The vaquita has no value as a commodity: It is too shy and small ever to support an ecotourism venture. It is not a vital link in the marine food chain. There is no cure for any human disease lurking in its liver proteins. It is just a lowly beast trying to make its way, like the rest of us. Its loss would barely be noticed.

Yet it was part of the magnificent diversity of life on Earth that our generation inherited, and it is rapidly becoming part of the dwindling legacy we are leaving behind. We have a year or two now to decide whether we are going to let this species live, or whether, like the baiji, we vote it off the island and wipe that little black smile off the face of the Earth forever. □

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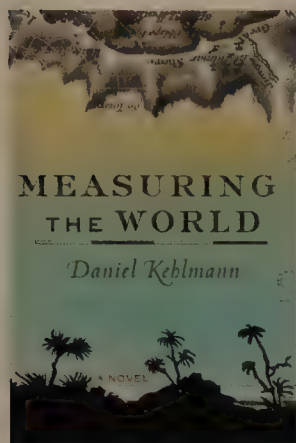
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And the Reading Is Easy

Summer has come around again (at least for readers north of the equator), and it's time to catch up on those books that have been piling up by the bedside. In anticipation of my vacation, I have relocated the accumulated pile to a spot near the patio door. As in past years, I've chosen titles that have characters, settings, or plots related to natural history or science. Enjoy!



Measuring the World by Daniel Kehlmann (Pantheon Books; \$23.00)

Daniel Kehlmann's droll confabulation, set in the age of Napoleon, features an unlikely pair of comic

heroes. Alexander von Humboldt, the very archetype of the intrepid explorer, has spent five years in the wildest parts of South America in the opening years of the nineteenth century, where he has climbed the Andes and canoed the Amazon.

Carl Friedrich Gauss, the pensive counterfoil to the Humboldt character's frenetic activism, has been a mathematical wunderkind. While staying close to his home in Prussia, Gauss has invented mathematical techniques that reveal the underlying unity of the cosmos. He has discovered how to predict the motions of asteroids and comets, and formalized the geometry of curved space that Einstein will borrow almost a century later to construct the general theory of relativity.

Kehlmann's protagonists meet at a scientific congress in 1828, each suffering a supposed midlife crisis, and in a series of interlocking flashbacks they replay scenes from the high points in their careers. Their stories are so familiar to historians of science that, stripped of the author's wry imaginings, the novel could almost serve as a straightfaced Wikipedia entry: Humboldt wrestles with electric eels along the Orinoco River, stupefied by the thrill of discovery—and by the

unforeseen amperage. Gauss astounds his schoolmaster by summing all the numbers from 1 to 100 in an eyeblink. But as with all good comedy, the humor is in the timing and phrasing. Re-animated by Kehlmann, Humboldt and Gauss sardonically observe life and the universe with two centuries' worth of hindsight. "So much civilization and so much horror," muses Humboldt, viewing the ruined pyramids of Mexico. "The exact opposite of everything that Germany stood for."

Tomb of the Golden Bird by Elizabeth Peters (Harper; paperback, \$9.99)

Egyptologist Amelia Peabody Emerson has appeared in nearly a score of books so far, and the body count keeps rising. Murder and mayhem, however, are not the main attractions of these mannered and chatty mysteries. Open to any page and you enter a vanished world, colonial Egypt of the early twentieth century, where wealthy amateur archaeologists putter around the ancient ruins along the Nile, looking for knowledge, fortune, and fame (not necessarily in that order)...while saving plenty of time for tea and gossip.

In this installment, Mrs. Emerson and her husband, Professor Radcliffe Emerson ("the greatest Egyptologist of this or any other century"), along with a large entourage, have just arrived for another season of digging in the Valley of the Kings. Soon

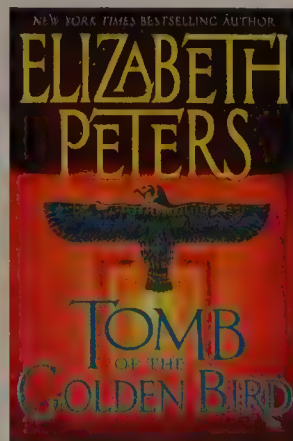
everyone is atwitter with news that Howard Carter, an archaeologist in the employ of Lord Carnarvon, has uncovered the steps of the tomb of the Pharaoh Tutankhamen. (Carter and Carnarvon, of course, like King Tut, are the names of real historical figures.)

The discovery attracts the usual bands of local grave robbers and envious rival scientists. But a greater mystery is: who is keeping the Emersons under surveillance? The appearance of Professor Emerson's brother Sethos, a sometime agent for British Intelligence, only adds to the sense of foreboding. What is the meaning of the coded message he has purloined?

Peters, who holds a Ph.D. in Egyptology from the University of Chicago, clearly is enchanted by the genteel life of bygone colonial days. What with frequent banquets, and so many family members, servants, and antagonists that you will find yourself flipping frequently to the four-page cast of characters at the front of the book, it's hard to keep track of who is chasing whom and why. Yet if the plot moves with the leisurely pace of the Nile, what's the hurry? Mrs. Emerson is appealingly engaging, the Professor appropriately eccentric, and the exotic setting sufficiently authentic to make one sad when it's time for the Emersons and their entourage to board the steamer back to England.

Mr. Thundermug by Cornelius Medvei (HarperCollins; \$14.95)

The idea of a talking animal is hardly a new one. Tale-spinners from Aesop to E.B. White have created memorable animal characters that endear and educate; serious satirists have often resorted to nonhuman commentators to cast the human condition into sharp relief. Mr. Thundermug, the eponymous baboon of Cornelius Medvei's smart novella, belongs in the latter category, I suppose, since his temperament is closer to Woody Woodpecker's than to Winnie the Pooh's. In spite of considerable facility with verbal expression, he can't help making himself an-





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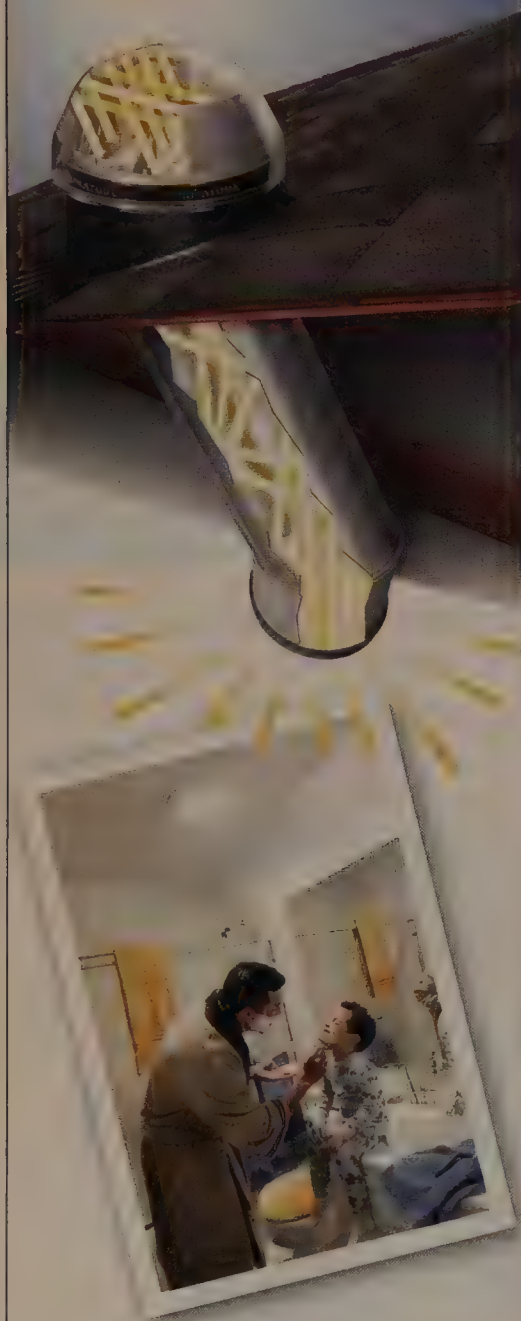
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BOOKSHELF: AT THE BEACH

noying to small-minded bureaucrats.

With his wife and two children, Mr. Thundermug has moved into a derelict apartment in a nameless city, where, as with so many immigrants, his very presence seems to irritate the authorities. The Housing Department wants him to register for assistance finding better lodgings, and frets that his illegal squat is infested with cockroaches (in fact, Mr. Thundermug and his family have already eaten them all). The City Council insists he send his children to public school (though, unlike their father, they can neither speak nor read). Eventually Mr. Thundermug is arrested on charges of indecent exposure, for walking around without clothes. He is also charged with cruelty to animals, since he is harboring a family of baboons in his apartment.

Cornelius Medvei's red-rumped hero is presented so matter-of-factly that it's tempting to think of his tale as a combination of magical realism and

shaggy-dog story. In structure, the short absurdist chapters resemble the *Ficciones* of Borges; and the juxtaposition of the mundane and the fantastic recalls passages from Gabriel García Márquez. But this is summer reading, and it would be unfair to ask too much of such a lightly drawn character. Eloquent as he is, Mr. Thundermug is as much buffoon as baboon, more like one of the befuddled eccentrics in James Thurber's "Fables for Our Time" than a symbol of the human condition.

ALSO WORTHY OF MENTION

Please, Mr. Einstein by Jean-Claude Carrière (Harcourt; \$22.00) and *A Madman Dreams of Turing Machines* by Janna Levin (Alfred A. Knopf; \$23.95)

Two books, the first by a writer, the second by a moonlighting astrophysicist, take us into the scientific mind. In Jean-Claude Carrière's book, as in the film *My Dinner with Andre*, the only action is an intense conversation. An anonymous twenty-first-century student meets Einstein in a nondescript office in Central Europe—and Einstein chats about the questions that concern him most: time, existence, the nature of space, and the meaning of life. It's all great fun, as long as you realize that the voice is that of the author as much as that of Einstein.

In contrast, Janna Levin strives for more historical verisimilitude, knitting together episodes from the troubled lives of the logician Kurt Gödel, who showed that there are true statements in mathematics and logic that can never be proved, and the mathematician Alan Turing, who pioneered the development of computing machines. Levin turns dry history into a literate and revealing examination of the power and the peril of creative genius.

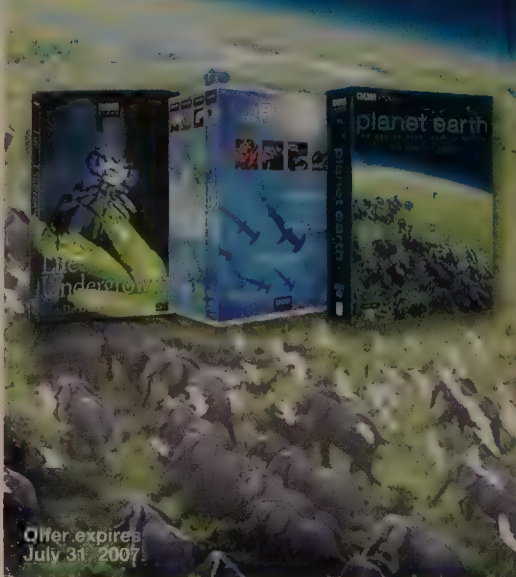
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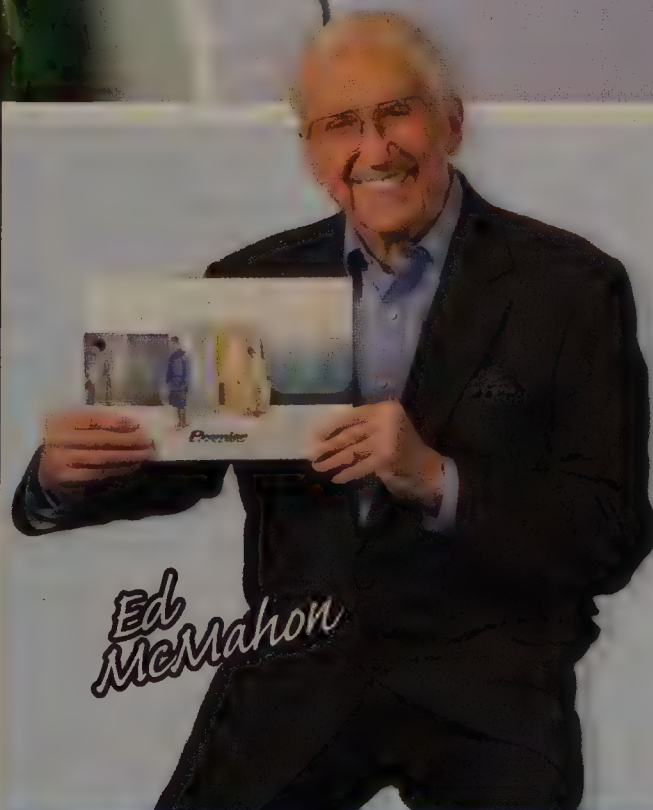
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Mercury gradually emerges into view as a morning object in July. Beginning around the 14th, look for it with binoculars low in the east-northeast sky about thirty or forty minutes before sunrise. From the 15th through the 28th, the planet rises in the dawn's early light before 4:30 A.M. local daylight time. On the 20th Mercury reaches its greatest western elongation, or apparent angular separation from the Sun: twenty degrees. After that, it becomes easier to see: from magnitude +0.3 on the 20th, Mercury brightens threefold by August 1st.

You might still be able to catch the planet as late as August 4th, when it rises about an hour before the Sun. Thereafter, the twilight glow will likely hide it from view, as Mercury swings behind the Sun from our earthly perspective, arriving at superior conjunction on the 15th.

Venus, a prominent evening object since January, relinquishes the title of "evening star" by the beginning of August. Its departure is dramatic. On July 1st Venus is still well up in the west-northwest sky at sunset, closely accompanied by a much dimmer Saturn (the two planets are separated by just eight-tenths of a degree). On the 8th Venus attains its greatest brilliance in the evening sky, blazing at magnitude -4.5. But by then it is noticeably lower in the sky at sundown, and it sets just two hours later. By the end of July, Venus sets only forty-five minutes after sunset; you'll need a clear and unobstructed horizon to spot it.

A few days into August the planet is gone from the evening sky. It sweeps between Earth and the Sun (inferior conjunction) on the 18th; then, just a week later, it emerges as a morning object, rising about forty-five minutes before sunrise. By the end of August Venus rises around 5 A.M. local daylight time. Throughout much of July and again toward the end of August, Venus appears as a beautiful crescent in telescopes and even in steadily held 7× binoculars.

Mars continues to approach the Earth slowly during July and August, and so becomes increasingly obvious in the late night and early morning sky. On July 1st the planet rises with the constellation Aries, the ram, in the east-northeast before 2 A.M. local daylight time, shining like a yellow-hued "star" of magnitude +0.7. By August 1st Mars moves into the constellation Taurus, the bull, rising around 12:45 A.M. and shining about 20 percent more brightly, at magnitude +0.5. The planet passes above the V-shaped Hyades star cluster on the 19th. By the end of August Mars rises just before midnight and has brightened to magnitude +0.3. By dawn, Mars is high in the southeast.

Jupiter is almost due south as darkness falls at the start of July, and sets in the southwest as dawn breaks, about five hours later. By the beginning of August, Jupiter emerges from the twilight in the south-southwest at dusk and sets before 1:30 A.M. local daylight time. By the end of August it is even lower in the southwest after sunset and sets at around 11:30 P.M.

Saturn begins July hovering just above dazzling Venus and follows Venus's plunge into the sunset fires as the month progresses. But you'll probably lose sight of it before Venus sets, particularly in the last week of July, because at magnitude +0.6 it is only about a hundredth as bright as Venus. Saturn becomes lost in the glare of the Sun throughout August, arriving at solar conjunction on the 21st.

The **Moon** is at last quarter on July 7th at 12:54 P.M. It wanes to new on the 14th at 8:04 A.M. and waxes to first quarter on the 22nd at 2:29 A.M. The full Moon takes place on the 29th at 8:48 P.M. In August, the Moon wanes to last quarter on the 5th at 5:20 P.M. and to new on the 12th at 7:02 P.M. Our satellite waxes to first quarter on the 20th at 7:54 P.M. and to full on the 28th at 6:35 A.M.

A total eclipse of the Moon is visible throughout much of the region encompassing the Pacific Ocean basin on August 28th. Alaska and particularly Hawai'i are excellent viewing spots, because there the entire eclipse plays out in the middle of the night. In New Zealand and eastern Australia the eclipse gets under way right after moonrise, and there, too, the view is not interrupted by the Sun. On the west coasts of Canada and the United States the eclipse ends just before moonset, shortly after the Sun rises. In the eastern third of the U.S. and in east-central Canada the Moon sets during totality; this past March in that same region the Moon was rising during totality. The Moon enters the Earth's umbra at 4:51 A.M. EDT/1:51 A.M. Pacific daylight time (PDT). Totality begins at 5:52 A.M. EDT/2:52 A.M. PDT and lasts ninety-one minutes. The Moon leaves the umbra at 5:24 A.M. PDT.

Because the Moon is new and out of the picture, conditions are excellent this year for observing the maximum activity of the **Perseid meteor shower**. The shower is predicted to peak this year during the late night and early morning hours of August 12–13. The best time to watch that night is between 11 P.M. and 5 A.M.; with a dark, unobstructed view of the sky, you might see between fifty and a hundred meteors per hour. The paths of the Perseids, if extended backward across the sky, appear to diverge from a spot in the constellation Perseus: hence the name "Perseids." In the early evening hours you won't see many meteors because Perseus is low in the sky. But as Perseus rises, the numbers should gradually increase until morning twilight interferes. The Perseids usually remain above a quarter of their peak intensity for one or two mornings before and a day after the maximum. You might even see an occasional member of the shower earlier or later than that.

Unless otherwise noted, all times are eastern daylight time.

Continued from page 19

they come from someone genetically identical to you, have all the hallmarks of an intruder. And the greater the genetic differences between donor and recipient, the more rapid and violent the immune response. That is why the few attempts to transplant animal organs, such as hearts, into people have been disastrous: the human immune system attacks the organ, quickly killing the alien tissue.

The fetal sheep doesn't reject the human stem cells, however, because the animal hasn't yet developed an immune system of its own. By the time its immune system does develop, it treats the implanted human cells as belonging there, recognizing that they were there to begin with. In principle, then, stem cells from your own bone marrow could be harvested and injected into a fetal sheep. Once inside the sheep, your stem cells would grow and develop into the organ you needed. The new organ could then be transplanted into you. And because it would be genetically identical to your own tissue, your immune system should not reject it.

As a place to start, the liver is of particular interest, because it can regenerate its own tissue. So if you needed a liver transplant, you wouldn't have to grow an entire human liver inside a sheep; it would be enough to have a human chunk.

At least, that's the idea. But my bet is that the human-organs-from-sheep scenario will never make it to the clinic. For one thing, there are questions of safety. New infectious diseases regularly jump into people from animals. HIV came from chimpanzees; SARS, from bats or civets. A transplant is an intimate contact, and animal cells may harbor viruses that, though harmless to their animal hosts, could be dangerous to people. Before transplants from animal tissues could go ahead, that risk would have to be assessed.

Continued on page 42

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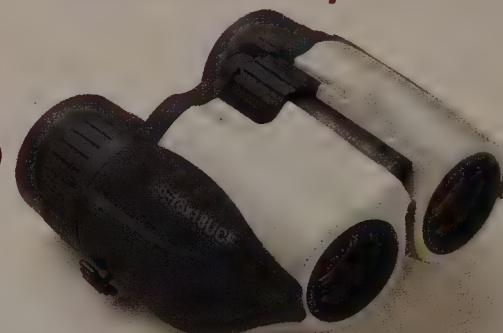
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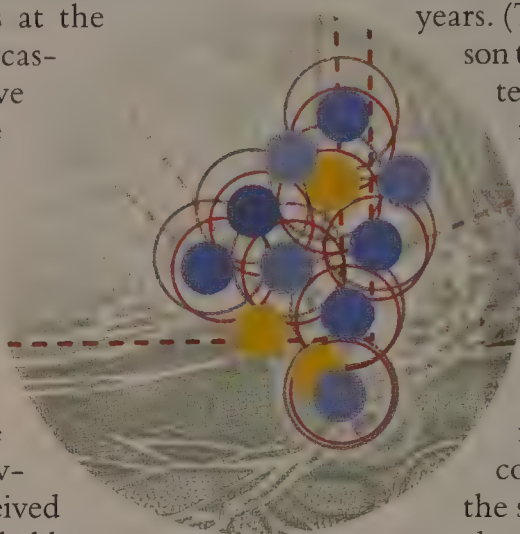
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LIFE ZONE

Continued from page 39

In any case, I think tissue engineers will be able to grow human organs in vats long before surgeons are ready to collect them from sheep. Tissue engineering, which involves coaxing stem cells to become various kinds of tissue, is advancing fast. Already, biologists at the University of Newcastle, in England, have grown a small cube of human liver tissue from stem cells collected from an umbilical cord; another group of investigators has just grown a heart valve. And in the United States, several people have received transplants of new bladders, grown from small pieces of their old ones.



But even if no organ is ever transplanted to a person from a sheep, the sheep that carry the human cells are fascinating in themselves. There are two reasons why.

First, despite the fact that people and sheep are not particularly closely related, the human cells do what they are told to do by the signals they receive from the surrounding sheep cells. They become liver cells, or muscle cells, and so on. That is remarkable: it shows that the signals have remained more or less unchanged since the ancestors of humans and sheep began evolving along their separate paths more than 75 million years ago. It leads one to ask, How far apart do organisms have to be on the evolutionary tree of life before cells from one species cannot respond to signals from cells of another species? Bets, anyone?

It turns out that cell transplants can also work between mice and chickens. Here, astoundingly, the animals in question have been diverging for more than 300 million years. Experimentally implanting the mouse cells

that are in charge of tooth development into crucial positions in early chicken embryos has led to chickens with teeth. The mouse cells send out signals that say, "Become teeth! Become teeth!"—and the chicken cells respond, even though birds haven't had teeth for about 80 million years. (The most likely reason the genes for making teeth have remained intact and functional in birds is that the genes are useful in some other way.)

And here's my second source of amazement at these chimeric, or genetically composite, beings. As the surgeon told me, as much as 15 percent of the cells throughout the bodies of

the sheep are human cells, not sheep cells. Yet the animals have no evident human characteristics. That makes me wonder how high a percentage of human cells a sheep could have and still be a sheep. Would you still have a sheep if half its cells were human? When would the system start to break down?

We've pretty much gotten used to the idea that the differences between species, or even individuals, can be comfortably defined in terms of DNA. But as developmental biologists learn how embryonic cells are transformed and guided, it is becoming increasingly apparent that an important part of what makes sheep sheep—and humans human—is how their bodies are laid out in early life. Will it prove possible, using mostly human cells, to build what to all appearances is a sheep . . . or vice versa?

OLIVIA JUDSON, a research fellow in the Division of Biology at Imperial College London, is the author of Dr. Tatiana's Sex Advice to All Creation: The Definitive Guide to the Evolutionary Biology of Sex (Owl Books, 2003).

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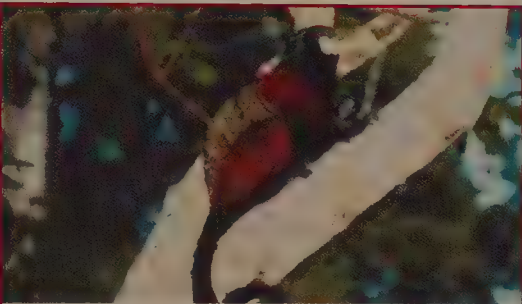


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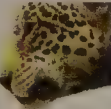


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New Jewel in Our Crown

One can only imagine the state of mind of the antimony miners in the Jiangxi Province of southeastern China as they carefully unearthed the spectacular stibnite now on view in the Museum's Grand Gallery, sparing it from destruction. The specimen's dramatic structure and brilliance, even against the bright white walls of the recently renovated first-floor Grand Gallery, cannot be overstated. As one youngster, training his camera on it, said, "I don't think I need the flash for this one!"

This rare and beautiful specimen is the largest on public display anywhere, unusual both for its size and for having so many freestanding crystals intact. Weighing one thousand pounds with hundreds of sword-like, metallic blue-gray crystals sprouting from a rocky base, it is sure to be as popular a

draw as the Star of India, the world's largest and most famous star sapphire, and the Patricia Emerald, one of the few large, gem-quality emeralds preserved uncut, both of which are housed in the Museum's Morgan Memorial Hall of Gems.

Stibnite (Sb_2S_3) is a compound of the elements antimony and sulfur, and this specimen is believed to have formed some 130 million years ago when water heated by volcanic activity dissolved those elements from surrounding rocks and then flowed between layers of limestone. It was donated to the Museum by mineral collector Marc Weill, founder and CEO of City Light Capital.

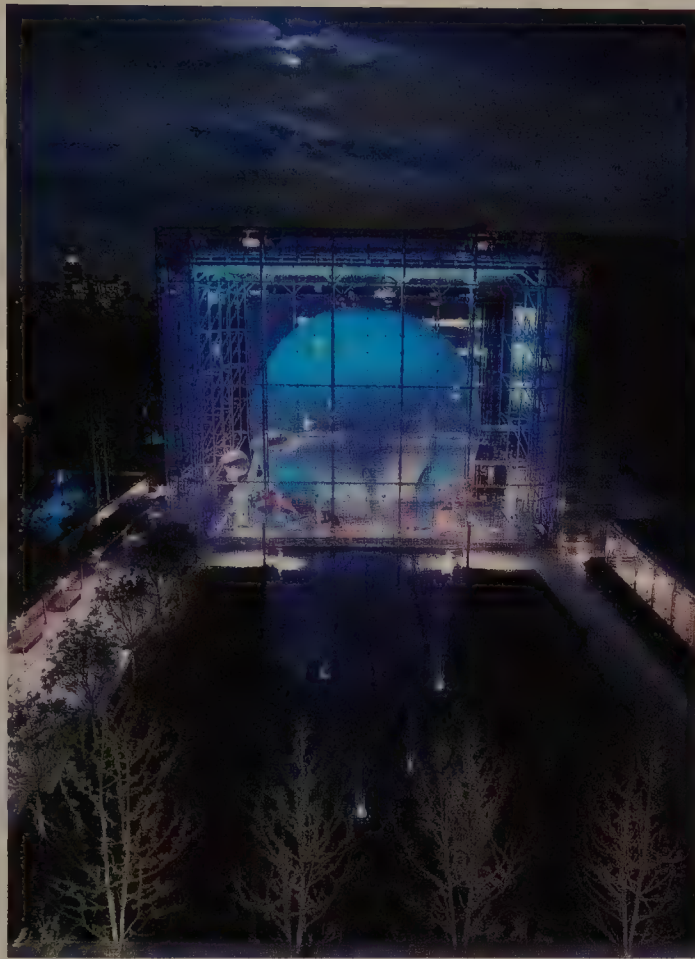
Stibnite today is mined for the antimony, which is used in matches, semiconductors, flame retardants, engine bearings, pottery enamel, and even some medications.



A close-up of the stunning stibnite specimen on display in the Grand Gallery

One Step Beyond

This is definitely not your parents'—or even your grandparents'—*American Bandstand!* One Step Beyond is a spectacular new multimedia program, teeming with live performances and world-class DJs and VJs spinning the latest music and projecting dynamic visuals while thousands of young professionals enjoy dancing and cocktails under the stars (and planets) in the Rose Center for Earth and Space. Held on select Fridays over the coming months, including July 27, September 14, October 19, and November 30, these out-of-this-world evenings are organized by the Museum in conjunction with *Flavorpill*, the cultural events email magazine.



D. FINNIN/AMNH

See and be seen at One Step Beyond, the Museum's new monthly party in the Rose Center.

PEOPLE AT THE AMNH

Beverly Heimberg

Assistant Director
Volunteer Services Department



D. FINNIN/AMNH

Beverly Heimberg oversees the more than 1,000 volunteers who contribute some 120,000 hours of invaluable service to the Museum every year, entering data, doing library searches for curators, staffing information desks, serving as tour guides and exhibition explainers, and more.

"We work with every department here," says Beverly, who selects the volunteers from "hundreds and hundreds of applications" that pour in, trains them, places them, and then makes sure they, as well as their supervisors, are happy. "These volunteers are extremely dedicated," she says, noting that in the case of tour guides and explainers, two of the most-sought-after positions, 30 hours of on-site training is required, followed by exacting tests of the volunteer's knowledge of the exhibition halls.

Volunteers range in age from high school students to retirees; there's even a 100-year-old volunteer emeritus, who assisted in the library for 30 years. Beverly herself was once a volunteer, then a paid assistant in the Department of Invertebrates, putting her bachelor's in biology to work in the field in Antarctica, Panama, and Florida. In 1997, armed with an M.A. in Museum Studies, she moved into her current position. She says she's able to keep her hand in science when training volunteers for new exhibitions. "I still learn," she says with obvious delight, "which is why they all still like being here too."

FROG SPOTTING

WWW.AMNH.ORG

Frogs may be elusive in the wild, but that's part of why they've thrived for more than 200 million years. The return of the delightful exhibition *Frogs: A Chorus of Colors*, with more than 200 frogs of more than 20 species spending their summer in re-created habitats, attests to the continuing popularity of these amazing amphibians. Now through September 9, the *Frogs* Web site, www.amnh.org/frogs, features the FrogCam, focused every day on as many as 9 different species and 75 living frogs in the popular centerpiece of the exhibition, the dart poison frog vivarium. Be sure to tune in each morning between 9:00 and 10:00 (Eastern Daylight Time) for mealtime!



T. GRANT/AMNH

Try to catch a glimpse of the blue dart poison frog at www.amnh.org/frogs.

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY 

www.amnh.org

EXHIBITIONS

Mythic Creatures: Dragons, Unicorns, and Mermaids
Through January 6, 2008
Mythic Creatures traces the origins of legendary beings of land, sea, and air. Cultural artifacts bring to light surprising similarities—and differences—in the ways peoples around the world have depicted these beings, and fossil specimens suggest a physical basis for the many forms they have taken.

Mythic Creatures: Dragons, Unicorns, and Mermaids is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with The Field Museum, Chicago; Canadian Museum of Civilization, Gatineau; Australian National Maritime Museum, Sydney; and Fernbank Museum of Natural History, Atlanta. *Mythic Creatures* is proudly supported by MetLife Foundation.



This Tibetan piece in *Mythic Creatures* represents Garuda, a minor Hindu deity, fighting with the snakelike Naga.

Frogs: A Chorus of Colors
Through September 9, 2007
This delightful live-animal exhibition introduces visitors to the colorful and richly diverse world of frogs, exploring their biology, ecology, and conservation.

Frogs: A Chorus of Colors is made possible, in part, by the Eileen P. Bernard Exhibition Fund. This exhibition is presented with appreciation to Clyde Peeling's Reptiland.

Gold

Through August 19, 2007
This glittering exhibition explores the captivating story of the world's most desired metal. Extraordinary geological specimens, cultural objects, and interactive exhibits explore and illuminate gold's timeless allure.

Gold is organized by the American Museum of Natural History, New York (www.amnh.org), in cooperation with The Houston Museum of Natural Science. This exhibition is proudly supported by The Tiffany & Co. Foundation, with additional support from American Express® Gold Card.

Undersea Oasis: Coral Reef Communities

Through January 13, 2008
Brilliant color photographs capture the dazzling invertebrate life that flourishes on coral reefs.

Beyond

Through April 6, 2008
Exquisite images from unmanned space probes take visitors on a journey through the alien and varied terrain of our planetary neighbors.

The presentation of both *Undersea Oasis* and *Beyond* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Exoplanets and the Search for Life

Two striking astronomical instruments demonstrate the need for extremely specialized tools in the search for planets around stars other than our own Sun.

This exhibit, part of the education and public outreach efforts of NASA's Navigator Program, was made possible through a grant from NASA's Michelson Science Center at the California Institute of Technology.



Watercolor of a Canadian lynx, John James Audubon, 1842

Unknown Audubons: Mammals of North America

The stately Audubon Gallery showcases gorgeously detailed depictions of North American mammals by John James Audubon, best known for his bird paintings.

Major funding for this exhibition has been provided by the Lila Wallace-Reader's Digest Endowment Fund.



Golden mantella frog

LECTURE



Yamada with Klingon killer worm and prehistoric horseshoe crab

Art/Sci Collision: Taxidermy Curiosities

Tuesday, 7/10, 7:00 p.m.

Artist Takeshi Yamada carries on the 19th-century tradition of "gaffs"—man-made objects passed off as real natural wonders or oddities, such as the chupacabra, fossilized fairies, and Fiji mermaids.

This program is made possible, in part, by the Allaire Family and Ruth A. Unterberg.

FIELD TRIP

Evening Bat Walk in Central Park

Friday, 7/20, 8:30 p.m.

Join the New York Bat Group for a bat walk through Central Park.



ROSE CENTER FOR EARTH AND SPACE

Sets at 6:00 and 7:30 p.m.

Friday, July 6

Friday, August 3

Visit www.amnh.org for lineup.

The 7:30 performance on August 3 will be broadcast live on WBOJ Jazz 88.3 FM.

FAMILY AND CHILDREN'S PROGRAMS

NEW! Field Trip to the Moon

Every Wednesday, 10:30 a.m.

Guided by a live presenter, this new program flies visitors to the Moon in the Hayden Planetarium.

AMNH ADVENTURES SUMMER CAMPS



P. MICKENS/AMNH

Neanderthal skeleton in the Spitzer Hall of Human Origins

Fossils and DNA

Monday–Friday, 7/23–27,

9:00 a.m.–4:00 p.m.

(For children entering grades 4 or 5)

AMNH Sampler Camp

Monday and Tuesday,

7/2 and 3, 9:00 a.m.–1:00 p.m.

(For children entering grade 1)

Mythic Creatures

Monday–Friday, 7/9–13,

9:00 a.m.–4:00 p.m. (For

children entering grades 4 or 5)

Monday–Friday, 7/23–27,

9:00 a.m.–4:00 p.m. (For

children entering grades 2 or 3)

Robotics

Monday–Friday, 7/9–13,

9:00 a.m.–4:00 p.m. (For

children entering grades 6 or 7)

Destination Space:

Astrophysics

Monday–Friday, 7/16–20,

9:00 a.m.–4:00 p.m. (For

children entering grades 2 or 3)

Monday–Friday, 7/30–8/3,

9:00 a.m.–4:00 p.m. (For

children entering grades 4 or 5)

Frogs

Monday–Friday, 7/16–20,

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Monday–Friday, 7/30–8/3,

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HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe

Fly Me to the Moon

Tuesday, 7/3, 6:30–7:30 p.m.

The Dark Side

Tuesday, 8/7, 6:30–7:30 p.m.

Celestial Highlights

Sizzling Summer Skies

Tuesday, 7/31, 6:30–7:30 p.m.

Welcome Autumn

Tuesday, 8/28, 6:30–7:30 p.m.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions

Journey into deep space to explore the hypersonic impacts that drive the formation of our universe. Narrated by Robert Redford.

Cosmic Collisions was developed in collaboration with the Denver Museum

of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum.

Made possible through the generous support of CIT.

Cosmic Collisions was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

SonicVision

Fridays and Saturdays,
7:30 and 8:30 p.m.

Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamspace.

Presented in association with MTV2 and in collaboration with renowned artist Moby.

IMAX MOVIES

Dinosaurs Alive!

On location with AMNH scientists past and present, this stunning new large-format film uses scientifically accurate, computer-generated images to bring to life these intriguing animals, from the earliest dinosaurs of the Triassic Period to the creatures of the Cretaceous.

IMAX films at the Museum are made possible by Con Edison.

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply.

All programs are subject to change.

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

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Inside Project Aquarius

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Lost Treasures of the Pirate Ship Whydah

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Jewels of India aboard Palace on Wheels

Nov '08

TBD

AMERICAN MUSEUM OF NATURAL HISTORY



EXPEDITIONS



AMNH Expeditions 2008

Family Programs

	Dates	Price*
Family China	June '08	TBD
Family Aegean aboard <i>Pantheon</i>	June '08	from \$6,995
Family Galapagos aboard <i>Santa Cruz</i>	June '08	\$5,190
Family Tanzania	Dec '08	\$6,990
Family Argentina	Dec '08	TBD
Family Antarctica	Dec '08	\$9,990

Discovery Cruises

	Dates	Price*
Belize Barrier Reef aboard <i>Le Levant</i>	Jan '08	\$4,990
Galapagos Islands aboard <i>Isabela II</i>	Jan '08	\$6,595
Rivers of West Africa aboard <i>Callisto</i>	Jan '08	from \$10,995
Tahiti & Marquesas Islands aboard <i>Spirit of Oceanus</i>	Feb '08	\$6,990
Egypt & the Nile aboard <i>Sun Boat IV</i>	Feb '08	\$6,890
Amazon Voyage aboard <i>Amatista</i>	Feb '08	\$3,598
Wonders of Patagonia aboard <i>VIA Australis</i>	Mar '08	\$7,990
World Leaders Symposium: China with George H.W. Bush aboard <i>SilverSea</i>	Mar '08	\$15,595
Costa Rica & Panama aboard <i>Le Levant</i>	Mar '08	\$7,590
Springtime in Japan aboard <i>Spirit of Oceanus</i>	Apr '08	\$9,290
British Isles aboard <i>Island Sky</i>	May '08	\$7,990
Sicily aboard <i>Le Levant</i>	May '08	\$6,695
North Pole Expedition: Global Warming Symposium aboard <i>Yamal</i>	June '08	\$30,990
Black Sea Voyage aboard <i>Le Levant</i>	Aug '08	\$6,995
China & the Yangtze River	Sept '08	TBD
Under Sail in Italy aboard <i>Sea Cloud</i>	Sept '08	from \$10,995
Treasures of Antiquity: Turkey & Greece aboard <i>Le Levant</i>	Sept '08	TBD
Australia's Great Barrier Reef aboard <i>Oceanic Princess</i>	Oct '08	\$6,990
Magnificent Mekong: Vietnam & Cambodia aboard <i>Mekong Pandaw</i>	Nov '08	TBD

* RATES LISTED ARE PER PERSON, BASED ON DOUBLE OCCUPANCY. SINGLE SUPPLEMENT PRICES ARE AVAILABLE; PLEASE CALL AMNH EXPEDITIONS FOR MORE INFORMATION.

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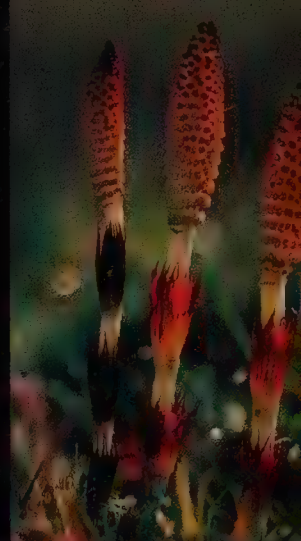
Admission to the Spider Pavilion is not included with regular Museum admission. Prices are:
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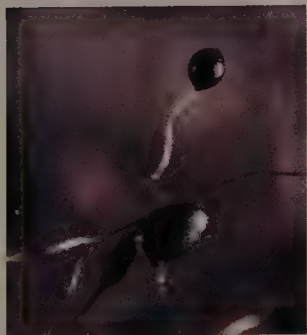
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THE NATURAL MOMENT

Over Easy

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THE NATURAL MOMENT

◀ See preceding two pages

Not many mothers would interrupt an afternoon nap and leave behind their six-week-old youngsters to seek out a thundering herd of wildebeests. But for this lioness in Kenya's Masai Mara National Reserve late one September afternoon, such a stampede was worth it. Peter Blackwell, who had been photographing the dozing feline family, trailed behind her.



Only a few hundred feet away from her cubs, the lioness came across an ostrich nest in the dirt, and promptly caused another female to ditch the young in her care. The ostrich on incubation duty wasn't prepared to fight for the nests' eggs, for several reasons. Only one ostrich egg in ten actually hatches—even in the absence of marauders. The few chicks that do emerge stand a good chance of being pilfered by other ostrich parents seeking to enlarge their broods. Finally, some of the eggs probably didn't even belong to the runaway ostrich: typically, several females lay their eggs in a single nest, scraped out by a male.

So with nothing but the eggs' size (six by five inches) and thickness (one-eighth inch) to slow her down, the lioness picked away. Blackwell watched her gorge on "many good eggs, but also several bad eggs, which exploded when she clamped down on them, leaving a rather disgusting smell." Unfazed and energized, the lioness resumed the wildebeest chase and made a successful kill.

—Erin Espelie

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UP FRONT

New Light on Dark Matter

You would think the first confirmed existence of vast amounts of dark matter in the universe would have been a big embarrassment for astrophysicists, the people who brought you the Milky Way, “island universes” of distant galaxies, and galactic superclusters. With all their attention to such luminous stuff, it turned out they were focusing on only a small fraction of what’s really out there. Still, there seemed little reason for astrophysicists to apologize for their ignorance: matter might be dark simply because it was too far away to see—just as a lot of stray rock in the solar system would be undetectable from the nearest star. And all the early evidence for the “missing mass” of the universe came from observations of incredibly distant objects: galaxies millions of light-years from Earth, clusters of galaxies a thousand times that far away.

But as Donald Goldsmith tells the story (“Dark Matter,” page 18), the real mystery emerged when cosmologists realized that dark matter is much darker, both observationally and metaphorically, than anyone had suspected. The success of big bang cosmology made it possible to calculate the abundances of the various atomic nuclei that formed in the first half hour after the primordial explosion that gave rise to everything. When protons and neutrons condensed out of a quark soup as the universe expanded, the strong nuclear force mediated their interactions, creating the earliest nuclei of hydrogen, helium, and a small smattering of heavier elements. Taking into account the primordial densities, the billion-degree temperatures, the strength of the nuclear force, and the expansion rate of the early universe, cosmologists came to the startling conclusion that most of the matter created in the big bang was not the stuff the things we know are made of, the ordinary matter built up out of the primary constituents of ordinary atoms. Instead, the dominant matter was “extra-ordinary,” and it was surely most of what later became known as “dark.”

• • •

That realization set the stage for a race that’s on today in the particle-physics community to learn the true identity of dark matter. The prize to the winner, aside from recognition by the administrators of Alfred Nobel’s estate, will be to become known as the discoverer of a universe even grander than the one we know. Experimental physicists at CERN, the European Center for Particle Physics just outside Geneva, expect to put the world’s most powerful particle accelerator into operation next year. If the CERN physicists confirm so-called supersymmetry, one of the leading theories of elementary particles (as many expect will happen), they will have the first evidence that the dark matter, so far detected only in distant galaxies, may actually be all around us. Millions of particles, each perhaps hundreds of times heavier than the proton, could be passing through our bodies—harmlessly, it should be emphasized—every second.

Before the great machine at CERN can turn on and rev up, there is still hope among experimenters working with smaller and simpler apparatuses that the glory of discovery could be theirs. They, too, are looking for a signal, a minivibration in a crystal or a microspike in the temperature of an inert gas, that would tell us all that dark matter—like a ghost from a parallel universe—is present here on Earth. The next few months will be an exciting time for the dark-matter sleuths.

—PETER BROWN

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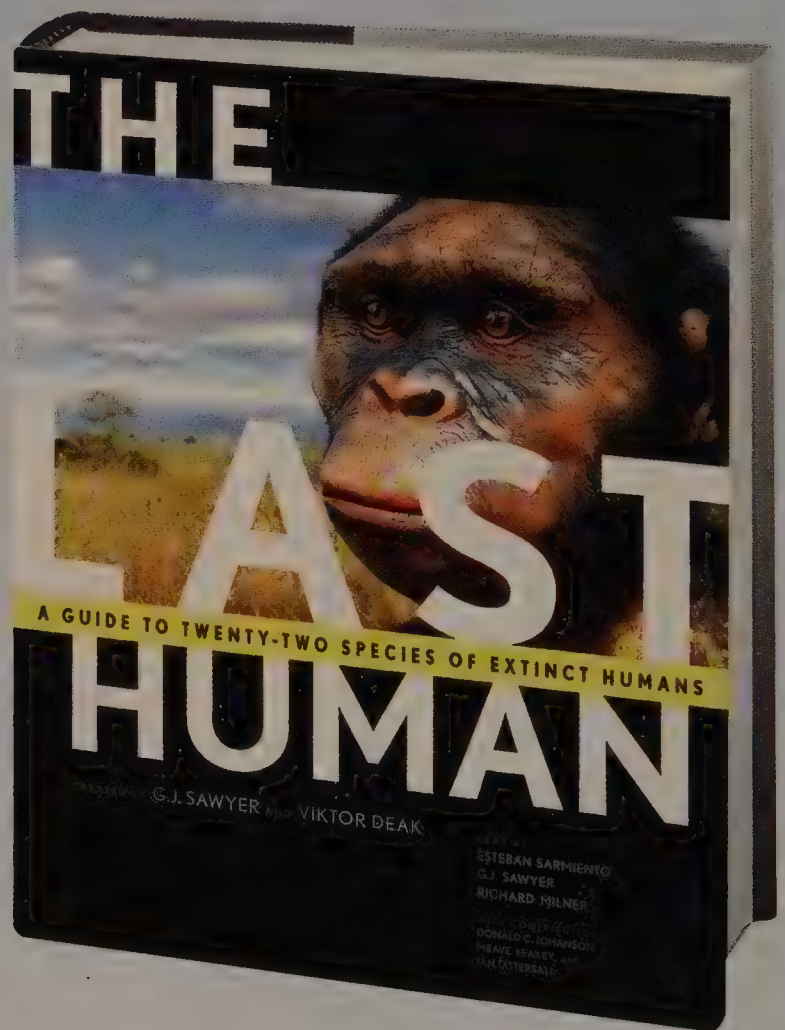
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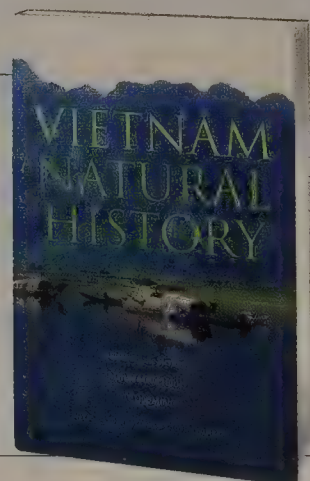
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CONTRIBUTORS

PETER BLACKWELL ("The Natural Moment," page 2) knows Masai Mara Reserve (MMR) and its inhabitants well. He was born in Kenya, grew up on a farm in the country's northern bushland, and spent many years as the resident naturalist at Siana Springs Tented Camp in the MMR. He has lent his expertise to a variety of international visitors, including the film crews for the BBC/Discovery Channel productions of *Big Cat Diary*, filmed twice a year since 1996. His own photographic work has been featured in several publications and has won awards in the United Kingdom and South Africa, but most often it serves as reference material for his paintings. Blackwell began attracting attention with his watercolors of African birds; now he works in many mediums, and chooses his subjects from a variety of wildlife in the African bush. Visit www.natureartists.com/peter_blackwell.asp to view some of his artwork.



DONALD GOLDSMITH ("Dark Matter," page 18) is a frequent contributor to *Natural History*. Trained both as a research astronomer and as an attorney, he devoted himself to popularizing astronomy more thirty years ago. In the ensuing years he has watched the dark-matter hypothesis develop from speculation to confirmation. Goldsmith has written or co-written more than twenty books, including *Connecting with the Cosmos* (Sourcebooks, 2002) and, with Neil deGrasse Tyson, *Origins: Fourteen Billion Years of Cosmic Evolution* (Norton, 2004), which was the companion book to the PBS *NOVA* series. Among his recent contributions to *Natural History* are "Turn, Turn, Turn" (December 2006/January 2007) and "Ice Cycles" (March 2007), both of which explain how the slow but periodic wobbles in Earth's journey through space may influence climate change. He lives in Berkeley, California.

JOAN E. STRASSMANN and **DAVID C. QUELLER**, a wife-and-husband team ("Altruism among Amoebas," page 24), focus their work on the evolution of altruism, cooperation, and the control of "cheating" (selfish) behavior. They point out that those issues lie at the heart of some of the most important transitions in evolution: the emergence of chromosomes, cells, eukaryotic (nucleated) cells, and multicellular organisms. After devoting twenty-five years to studying the behavior of social wasps—conducted in Tuscany with colleagues from the University of Florence—they have shifted most of the focus of their work to the study of microscopic social amoebas of the genus *Dictyostelium*, which they track through the soils of North America. The amoebas serve well as model organisms because they offer the right combination of sociality, short lifespan, and well-understood genetic features. Both Strassmann and Queller are Harry C. and Olga K. Wiess professors of ecology and evolutionary biology at Rice University in Houston, Texas, and both have held John Simon Guggenheim Fellowships.



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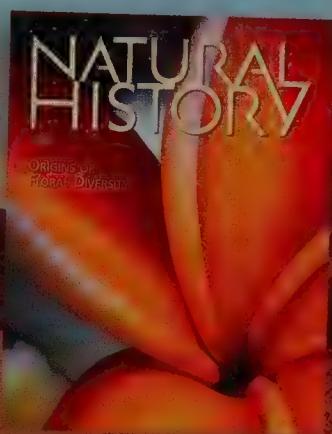
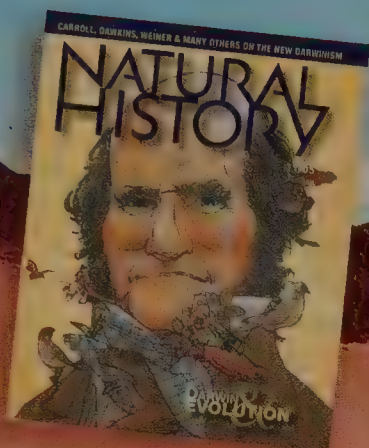
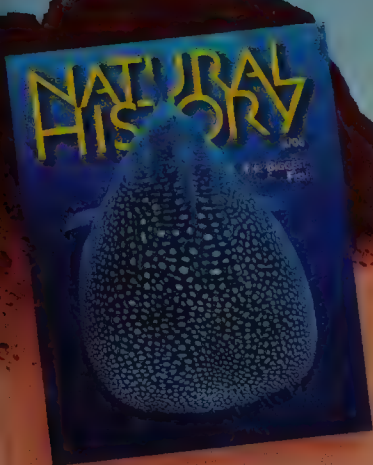
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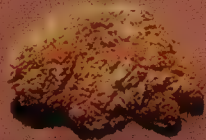
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LETTERS

Evolution on Trial

I congratulate Richard Milner for his review article ["Darwin in Court," 6/07]. As it happens, Randy Olson's film *Flock of Dodos*, which Mr. Milner discusses, was screened at "Evolution 2006," a meeting of evolutionary biologists held last year at Stony Brook University. Our audience did not need the cheerful determination of the creationists in the film to remind us of the threat they pose. Evolutionary biologists need to communicate the undeniable fact of evolution to the public. Creationism is not just a threat to a few intellectuals; it is the cutting edge of a broad attack on science

that endangers America's security, public health, prosperity, and liberty.

Michael A. Bell
Stony Brook University
Stony Brook, New York

I thoroughly enjoyed Richard Milner's article. I am a home educator and a Bible-believing Christian who holds to the Creation model. I find it very sad that the only educational setting that allows my children the freedom to examine both sides of the creation-evolution issue is home school. As a public school student in the 1970s and 1980s, I was never taught that evolution is theory, not fact. I also know people who grew up

in homes where questioning the Bible was never allowed. Both circumstances are deplorable. Challenging children to a debate sparks interest, creativity, observation, experimentation, and logical thinking.

Joelle White
Des Moines, Washington

RICHARD MILNER REPLIES: When I perform my own show, "Darwin Live," I often feel as if I'm preaching to the choir; the program at Stony Brook that Michael A. Bell describes was likely a similar tribal gathering of evolution supporters. As he suggests, the challenge is to reach out to those who are convinced that evolutionary studies promote moral

and social chaos, and attempt to convince them that, as Darwin famously stated, "there is grandeur in this view of life."

I appreciate Joelle White's willingness to explore these issues. If one is interested in teaching critical thinking, however, one shouldn't promote a false debate, which results when "intelligent design" is treated as science. The how, why, and wherefore of evolution are what scientists debate, not whether it is opposed to another "model" called creationism (Christian or otherwise).

I want to correct an error that crept into my text: William Paley, famous for the watchmaker anal-



ogy, lived from 1743 until 1805, and thus was not a "seventeenth-century" theologian.

Pregnant Response

In his article "Pregnancy Reconceived" [5/07], Gil Mor did not mention the extreme fatigue most women feel during the first trimester of pregnancy. That would seem to add further support for the inflammation hypothesis; the fatigue of early pregnancy appears very similar to that caused by severe influenza or by interferon treatment. Is there a measurable increase in interferon secretion during pregnancy?

Also, Dr. Mor did not

mention the trigger for the inflammatory process during the third trimester. What is the hypothesis about that?

Nurit Patt, M.D.

Albuquerque, New Mexico

GIL MOR REPLIES: For space and simplicity, the description omitted many symptoms, such as fatigue. At the implantation site there is an increase in the expression of interferon-gamma, which could enter the mother's circulation and, along with other cytokines, give rise to the symptoms described. The implantation site resembles an open wound, and inflammation is necessary to repair it.

We hypothesize that

in the third trimester the increasing cell death in the "aging" placenta may trigger the inflammatory response. But we have little relevant information about that stage of pregnancy.

Runs with Elephants

Adam Summers reports that the top speed of a running elephant is fifteen miles an hour, "no faster than a reasonably fit person could run in terror" ["A Spring in Its Step," 5/07]. I have a number of running friends who are considered "reasonably fit," and none of them could come close to running a four-minute-mile pace (fifteen miles an hour). I plan to keep my distance should I encounter

an elephant in the wild.

Pamela Maher

La Jolla, California

ADAM SUMMERS REPLIES:

People can sprint for cover far faster than they can run a mile. Nearly all of us could have caught Roger Bannister as he ran by on his way to the first four-minute mile; keeping up is the hard bit.

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Poor Bird, Rich Bird

Big gaps between rich and poor put species at risk, according to a new report that provides a subtle view of how wealth correlates with biodiversity.

Gregory Mikkelsen of McGill University and his colleagues compared local biodiversity with the distribution of wealth in forty-five countries, as well as in forty-five U.S. states. To rank biodiversity worldwide, Mikkelsen counted the number of plant and vertebrate species threatened with extinction; to measure biodiversity by state, he determined the fraction of each state's resident bird species that have suffered statistically significant

population declines during the past forty years. Economic equality was encapsulated in the "Gini ratio" of a country or state (a low Gini ratio signals a relatively equal distribution of wealth).

Mikkelsen's group discovered a significant correlation between equality and biodiversity both around the world and across the forty-five U.S. states. Where wealth is inequitably distributed, biodiversity suffers; where wealth is more evenly distributed, the natural environment benefits. It seems that a society that cares for its struggling human members also cares for its wildlife.

(PLoS ONE) —Nick Atkinson



Chile con Pollo

When the Spanish conquistador Francisco Pizarro arrived in what is now Peru in 1532, he found chickens already integrated into the local culture. But his observations of their presence sparked an academic controversy centuries later about how the chickens got there. Most historians think they arrived in the New World with Europeans around 1500,

but new evidence suggests an altogether different origin.

Alice Storey and Elizabeth Matisoo-Smith of the University of Auckland, along with their collaborators, radiocarbon-dated a chicken bone found among others several years ago at a Chilean archaeological site and analyzed its mitochondrial DNA. The site, El Arenal 1, lies on Chile's western seaboard and predates Co-



Motion of air around a flying bat is depicted by a computer-generated field of arrows.

Flip-Flop Flap

Given our human fascination with flight, it's no wonder that birds and their aerodynamics have been studied in great detail. Not so, however, the bat. And the mechanics of bat flight is at least as different from the mechanics of bird flight as . . . a bat is from a bird.

On the downstroke of a bird's wing during slow flight, for instance, the primary feathers form a solid plane that pushes downward and backward on the air, propelling the bird upward and forward. On the upstroke, the primaries separate, and much of the air that would push the bird back down rushes through the gaps instead. The wing of a bat, however, is a membrane that offers continuous resistance. What happens during its upstroke?

Anders Hedenström of Lund University in Sweden and his colleagues studied vortices in the wake of the Pallas's long-tongued bat, *Glossophaga soricina*, in the fog-filled air of a wind tunnel. At slow speeds, they discovered, both the downstroke and the upstroke push the animal up and forward. To move the bat forward and upward during the upstroke, the outer part of the wing flips upside down and flicks quickly backward. (At high speeds, the wing doesn't flip and part of it does push the bat down during the upstroke, but that resistance is at least partly compensated for by continuous lift on the front of the wing at the higher speed.)

Whether the flip-flop is common to all bats or an adaptation special to the ones that hover—such as *G. soricina*, a nectar-eater—remains to be seen. (Science) —Stéphan Reeb

lumbus. The bone, dated to the 120-year range between 1304 and 1424, suggests the ancient inhabitants of South America's western coast were probably feasting on roast drumsticks well before the Spaniards arrived.

So how did the chickens get to South America before Columbus? (They are clearly not native; domestic chickens are believed to be descended from

wild birds of the Indian subcontinent.) Storey's DNA analysis identified a genetic sequence in the El Arenal bone identical to one that occurs only in prehistoric chickens unearthed at archaeological sites in Tonga and American Samoa. The finding indicates that early Polynesian explorers likely sailed the Pacific with their favorite food on board. (PNAS) —N.A.

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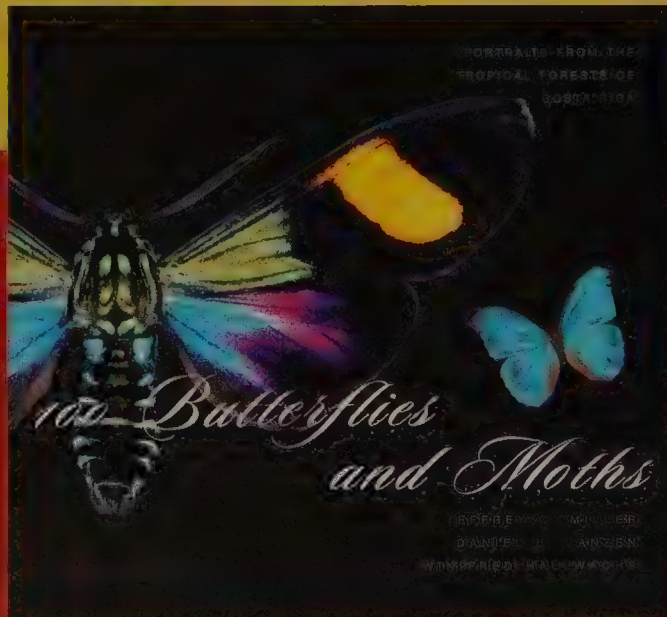
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A Lonely Future

The universe is expanding, and many cosmologists think the expansion will continue forever. Paradoxically, though, a new analysis shows, billions of years from now—if anyone is around to care—the evidence for both the expansion and the big bang will vanish and the universe will appear deceptively static.

Lawrence M. Krauss of Case Western Reserve University and Robert J. Scherrer of Vanderbilt University base their remarkable conclusions in part on Hubble's law, the strongest case for universal expansion. The law summarizes the observation that the greater the distance between Earth and a faraway galaxy, the faster they are moving apart. Krauss and Scherrer calculate that during the next 100 billion years, the expansion will take

galaxies beyond our local cluster so far away that they will be separating from the Milky Way faster than the speed of light. In effect, the more distant galaxies will become invisible—taking with them perhaps the most straightforward evidence for expansion.

What about the cosmic background radiation, a relic of the big bang and another key piece of evidence for universal expansion? Nope, its wavelength will increase beyond detectability as the universe expands. Tongue slightly in cheek, Krauss and Scherrer point out how lucky today's astronomers are to live in an era—admittedly a long one—when evidence of the true nature of the universe is still out there for us to see. (*Journal of Relativity and Gravitation*) —S.R.

Radiation: It's What's For Dinner

Fungi are well-known for breaking down organic material, not creating it from scratch, as plants do. But a fungus that might break that mold has been discovered thriving at one of the most toxic sites in the world: the defunct Chernobyl nuclear reactor.

The black fungus *Cladosporium sphaerospermum* was collected from the reactor walls by a robot touring the radioactive site, and it caught the attention of Arturo Casadevall of the Albert Einstein College of Medicine. Intrigued by the phenomenon, Casadevall, Ekaterina Dadachova, also of Einstein, and their colleagues exposed colonies of *C. sphaerosper-*



Russian double burial (artist's depiction)

Deaths, Foretold

Did Stone Age Europeans practice ritual human sacrifice? The large number of graves holding multiple dead, including some with abnormal skeletons or lavish funerary ornaments, have led Vincenzo Formicola of the University of Pisa to think they might have.

Six of the thirty graves known in Europe from between 28,000 and 23,000 years ago hold more than one skeleton—a higher-than-expected frequency if the deaths were natural. In one Russian grave, two children were buried head-to-head, along with spears and ivory ornaments: pendants, carvings, and some 10,000 beads. The abundance of goods implies either that the children enjoyed the wealth of high class—unlikely in a hunter-gatherer society—or that the goods took so long to craft that the ceremony was planned well in advance. And that suggests the children were sacrificed.

The Russian grave as well as two others—a Moravian triple burial and an Italian double burial—each held one young person with abnormal skeletal development, who would have been noticeably impaired in life. Formicola notes that the burial of such “select” individuals together with physically normal people is consistent with ritual sacrifice. Many scholars contend, however, that less remarkable practices could account for the unusual graves. (*Current Anthropology*) —S.R.



Belly of the beast: inside the Chernobyl nuclear reactor

mum and two other species of fungus to extravagantly high levels of radiation in the laboratory. Radiation, they discovered, increases the growth of species that have melanin, the dark pigment that also occurs in human skin. Furthermore, when the investigators irradiated melanin in isolation, they noted dramatic changes in its electronic properties. Melanin seems to capture energy from radiation and convert it to chemical energy, much the way chlorophyll in plants captures the energy of sunlight.

If *C. sphaerospermum* and the numerous other fungi that make melanin are indeed able to “radiosynthesize,” fundamental equations describing the Earth's energy balance might need to be recalculated. (*PLoS ONE*)

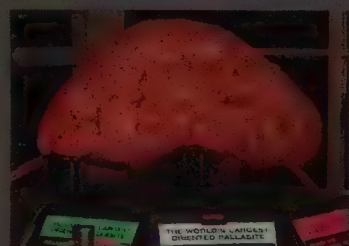
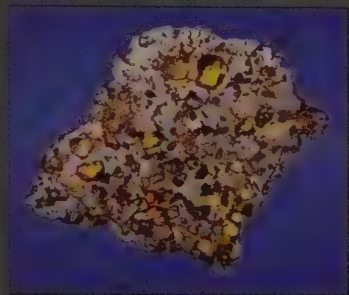
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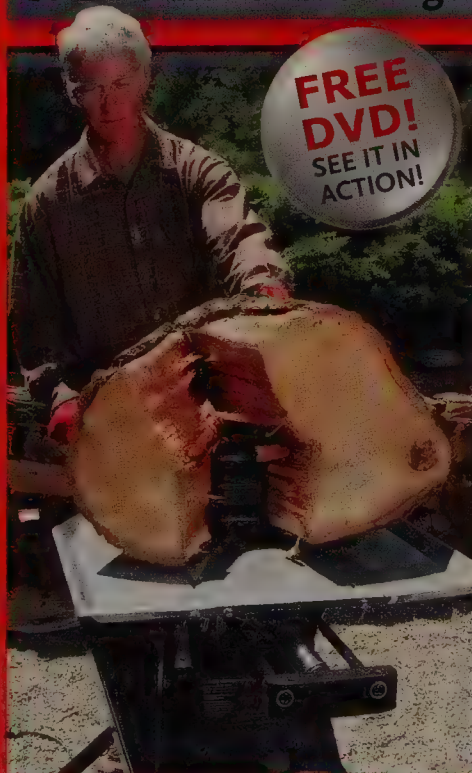


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Green for the Green

The European Union's "cap-and-trade" system for regulating carbon dioxide (CO₂) emissions is being hailed as an important first step in addressing global warming. Beginning in 2005, the twenty-five (now twenty-seven) EU countries have each been assigned an annual CO₂ quota, a maximum allowable amount of CO₂ emissions, which the countries then apportion among various large indus-

trial emitters. If one company needs to exceed its allowance, it can buy unused allowances from another. The market for allowances effectively puts a price on CO₂ emissions.

A. Denny Ellerman of M.I.T. coordinated a symposium of papers to examine how well the system—called the Emissions Trading Scheme—is working. In 2005, nineteen of the participating countries released less CO₂ than their

quotas allowed. Overgenerous allowances, now slated for reduction, may account for some of that success. But the high cost of over-emitting probably helped too. In the first year of trading, emissions allowances sold for as much as U.S. \$33 a ton and about \$19 billion in allowances have been traded to date. Furthermore, analysts estimate, under the cap-and-trade system the EU pumped about 4 percent less CO₂ into

the atmosphere than it otherwise would have.

Why do countries adhere to a scheme that forces their industries to pay if they're not green? In Europe, having a green conscience and securing the full economic benefits of EU membership seem incentive enough. The trick will be to make something similar work on a global scale. (*Review of Environmental Economics and Policy*) —S.R.

Heat Waves

Oceanic planetary waves, just an inch or two high at the surface but thousands of feet deep and hundreds of miles apart, sweep slowly but steadily across Earth's oceans: a surfer who caught one in Acapulco would take four years to wash up on a Chinese beach. The waves are speeding up, though, thanks to global warming, and as they do, they could affect weather patterns around the world.

The waves are constantly generated by surface winds and pushed westward by the Earth's eastward rotation. They advance by between four and ten inches a second in the tropics, more slowly toward the poles. But that's about 10 percent faster than oceanic planetary waves traveled at the start of the Industrial Revolution 200 years ago, according to John C. Fyfe and Oleg A. Saenko, both at the Canadian Centre for Climate Modelling and Analysis in Victoria, British Columbia. What's causing the speedup? Global climate models point to the temperature increase in the upper ocean—a consequence of increased atmospheric carbon dioxide. By 2100, the investigators add, if carbon dioxide levels rise as predicted, the waves will travel 35 percent faster than they did in preindustrial times.

Oceanic planetary waves affect ocean currents, which strongly influence continental weather and climate. As the waves speed up, Fyfe and Saenko forecast big changes that may include more frequent El Niño events and heat waves across western North America and Europe. (*Geophysical Research Letters*) —Harvey Leifert

A surfer catching one of the waves in Acapulco would take four years to wash up on a Chinese beach.

No Place to Hide

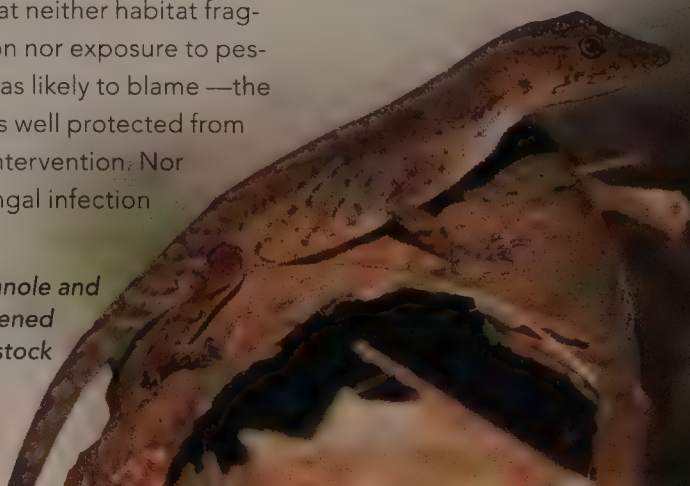
No ecosystem, it seems, is immune to the effects of climate change. Take La Selva Biological Station, an old-growth forest reserve in the lowlands of Costa Rica. Night temperatures there have risen, an effect of global warming, and the annual number of dry days has dropped by half since 1970. In the same period the abundance of frogs, salamanders, and lizards has plummeted by 75 percent.

Coincidence? Steven M. Whitfield and his graduate advisor Maureen A. Donnelly of Florida International University don't think so. As they and a team of colleagues documented the animals' decline, they found that neither habitat fragmentation nor exposure to pesticides was likely to blame—the reserve is well protected from human intervention. Nor was a fungal infection

that has decimated frog species in mountain areas: at La Selva there is no sign of the disease, and reptiles are impervious to it anyway.

Whitfield and Donnelly suspect that the increasingly warm and wet weather has resulted in fewer leaves falling and has hastened the decomposition of leaf litter on the ground. That litter is what the frogs, salamanders, and lizards call home, and so those two effects would lead to a shortage of real estate. Moreover, because the drastic population decline has happened gradually, it may be going on unnoticed elsewhere in the tropics. (*PNAS*) —S.R.

Ground anole and its threatened housing stock



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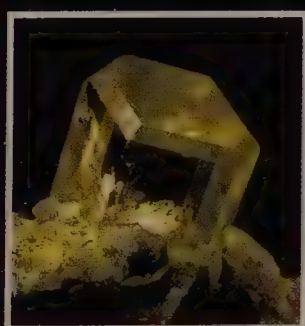


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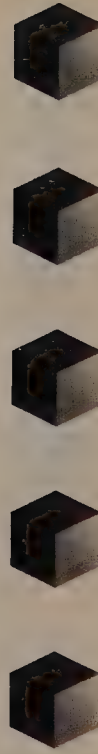
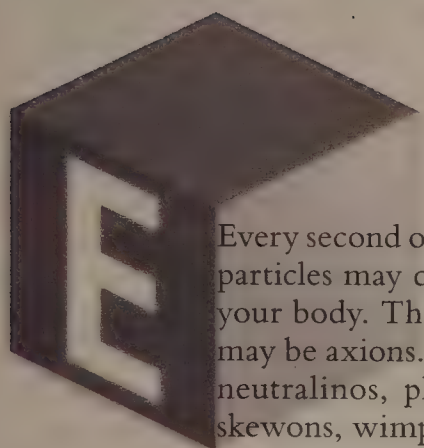
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DARK MATTER

MOST OF THE MATTER
IN THE UNIVERSE IS NEITHER
BOUND UP IN STARS OR PLANETS
NOR DISPERSED IN CLOUDS
OF "ORDINARY" PARTICLES.
EXPERIMENTERS ARE RACING
TO ANSWER THE QUESTION,
WHAT IS IT MADE OF?

By DONALD GOLDSMITH



Every second of every day, millions of dark-matter particles may course through every cubic inch of your body. The particles may be WIMPs, or they may be axions. They may be higgsinos, majorons, neutralinos, photinos, pyrgons, quark nuggets, skewons, wimpzillas, or zinos. If you choose, you can ignore these whimsically named creatures of the cosmos, just as they ignore you: they steadfastly refuse to interact with any of the particles that form you. Then again, maybe these strange particles don't exist at all.

Astronomers readily admit that they don't know what dark matter is—just that it dominates the universe. You might conclude that this predicament has plunged astronomers into a pit of professional confusion, from which they are trying to escape by creating a virtual cosmos out of hypothetical matter. And you'd be partly right. But astronomers have also gained remarkably firm knowledge of dark matter, hard as that seems to square with the continuing obscurity of its identity.

First and foremost, dark matter—matter that emits neither light nor any other detectable form of radiation—is real, notwithstanding the struggles of a small minority of physicists to explain it away. It was created immediately after the big bang, 14 billion years ago, and has persisted ever since, forming the bulk of all the matter in the cosmos. In spite of its mysteries, dark matter is detectable through a web of observations that complement and support one another. In fact, American and European physicists are racing to catch its invisible particles in new, ever improving detectors. What excites them is the sense that they are closing in on the answer to one of the great cosmic riddles: What is most of the universe made of?

What makes astronomers so sure that dark matter exists? The answer is gravity. All matter, including invisible matter, exerts gravitational forces on the matter we can see.

Fritz Zwicky, the prickly Bulgarian-Swiss-American astronomer who was the first to conclude that dark matter must exist, introduced the concept in 1933. By applying Newton's laws and measuring the speeds of individual galaxies within a cluster of galaxies, Zwicky could deduce the mass of the cluster. He also determined the amount of visible matter in the clusters by measuring the brightness of the galaxies that form them. Those two measurements showed that a typical giant cluster of galaxies comprises at least ten times more invisible matter than what is visible. Later observations would rule out the possibility that the invisible matter is all made up of diffuse gas floating among the galaxies. Such intergalactic gas does exist, but in nothing remotely like the quantities needed to account for most of the dark matter.

Zwicky's conclusions gained scant attention from his colleagues. The snub was partly provoked by his cantankerous nature—he referred to fellow astronomers as “spherical bastards,” meaning that they were bastards no matter how you looked at them. But a greater hurdle was the revolutionary implication of his idea: few could accept that most of the universe remained to be discovered.

So dark matter suffered three decades of neglect. Then in the 1970s two astronomers at the Carnegie Institution of Washington (D.C.), Vera S. Rubin and W. Kent Ford Jr., mapped the motions of stars within galaxies close to our own Milky Way. They reached essentially the same conclusion as Zwicky had: each galaxy includes enormous amounts of

dark matter, far more than all the luminous stuff in the galaxy's stars. The bulk of it forms a giant, dark halo extending far beyond the star-strewn galactic expanses that we see.

Astronomers today, applying Zwicky's logic, are still detecting vast quantities of dark matter in distant galaxy clusters. Among the clusters, they have observed clouds of hot gas, which would have escaped the clusters' gravitational pull billions of years ago if the clusters had no more mass than that of their stars.

Impressive as those observations are, there's even more evidence for the unseen presence of dark matter: the phenomenon of "gravitational lensing." Because gravity bends space itself (Einstein's finest insight into nature), light passing close by a massive object deviates from a straight-line trajectory. Hence if a massive object happens to lie almost directly along our line of sight to a more distant source of light, such as a galaxy, the light we see will be bent or even focused, much as if the intermediate object were an optical lens [see illustration on opposite page]. A small

amount of light bending, or "lensing," can distort the galaxy into an unusual shape, just as the thick glass bottom of an old Coke bottle distorts the shape of a light bulb when you look at the bulb through the bottle. Stronger lensing can actually create multiple images of the same light source. Gravitational lensing enables astronomers to map the distribution of all matter, not just visible matter, because all matter can give rise to a lensing effect.

What, then, is this dark matter that makes up by far the bulk of all the matter in the universe? No one knows. But cosmologists do know one thing for sure: most of it cannot be anything like the matter familiar to us.

Cosmologists classify all matter into two kinds: baryonic and nonbaryonic, or, basically, the ordinary and the exotic. "Baryon" comes from the Greek root *barys*, meaning "heavy"; the term was coined to refer to the heavy particles that fuse together in the nuclei of ordinary atoms—neutrons and protons. They far outweigh the electrons, which are leptons, or "light" particles, not baryons. With the realization that matter exists in more exotic forms, the term "nonbaryonic" came to denote not only leptons but also all other particles that do not participate in nuclear fusion. One of the most important clues to the mystery of dark matter comes from the growing evidence that the bulk of it—and thus, most of the matter in the universe—is nonbaryonic matter.

Baryonic matter forms stars, planets, moons, and even the interstellar gas and dust from which new stars are born. Nonbaryonic matter includes neutrinos, tiny particles each having less than a millionth the mass of the already diminutive electron. Neutrinos were once regarded as likely candidates for dark matter because they exist in such prodigious numbers, but they have now been excluded from the dark-matter sweepstakes. Detailed studies of how galaxies form suggest that dark matter is most likely made of particles whose masses range from roughly that of the proton to several hundred times as much.

How do astrophysicists infer that such hypothetical particles of dark matter must be nonbaryonic? They can estimate the total amount of matter from the effects of gravitational lensing and the distribution of cosmic background radiation. The baryonic part of that total then comes from the current understanding of how the cosmos behaved during its earliest epochs. The big bang, with which the universe began, opened an era of nuclear-fusing fury, a time when all particles



Map of dark matter (light blue), digitally superposed on a photograph made by the Hubble Space Telescope, shows that a giant ring of invisible mass surrounds the dense core of a giant cluster of galaxies called ZwC10024+1652, about 5 billion light-years from Earth. Astronomers mapped the distribution of mass in the galaxy cluster by observing the effects of gravitational lensing on background galaxies.

crowded together at unimaginably high densities and temperatures. All creation then resembled the cauldron at the core of a star, only far more so. From the countless nuclear fusions that took place in those first few minutes after the big bang, there emerged the basic ratio of nuclei in the universe today: almost entirely hydrogen and helium, with only a minute smattering of all heavier nuclear varieties.

By the end of its first few minutes, the universe had expanded and cooled, dipping below the billion-degree temperatures needed for nuclear fusion. Only in much later, highly localized events did the stars cook up almost all the heavier elements, such as the carbon, nitrogen, oxygen, silicon, and iron that make up our planet and ourselves. Those heavier nuclei, however, comprise no more than 2 percent of the mass of all baryonic matter. The other 98 percent is still made up of hydrogen, helium, and their isotopes, created immediately after the big bang. By measuring the relative amounts of the various isotopes of hydrogen and helium nuclei, cosmologists can deduce how much baryonic matter took part in the great crucible of cosmic nuclear fusion in the first half hour of the universe.

Those results, now confirmed by detailed studies of the cosmic background radiation, lead to a startling conclusion. Baryonic matter—some of it in stars, but much more in diffuse interstellar gas—forms no more than a sixth of all matter in the universe. The other five-sixths must be nonbaryonic matter, either in the form of elementary particles or clumped into much larger objects.

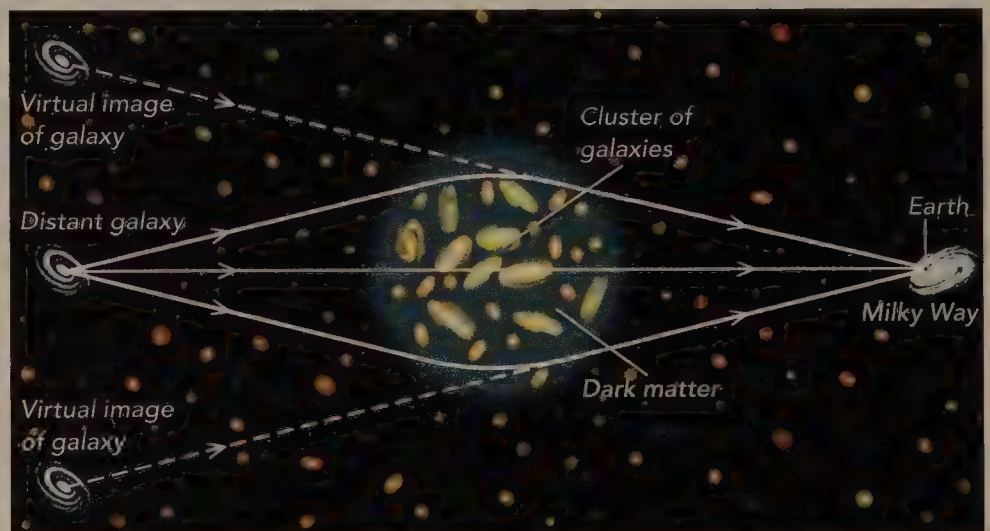
The fascination with the unruly properties of dark matter—its distribution in space, and most of all its predominantly nonbaryonic nature—has given rise to a flourishing dark-matter community. Some members can point to achievements such as improved maps of dark matter and its distribution in intergalactic space [see illustration on the following two pages]. Others strive to design, build, and operate experiments that may someday determine the nature of nonbaryonic dark matter, or at least eliminate from contention some of the hypothetical particles that elementary-particle physicists have proposed.

Before surveying those experiments and the hypotheses that motivate them, it's worth noting that a few ingenious minds will have none of the dark-matter mystery. Instead, they suggest, the observations show merely that physicists don't yet

fully understand gravity. Suppose that at the greatest cosmic distances, gravitational forces deviate slightly from what Newton proposed and Einstein refined. In that case, the motions of stars and galaxies might not reflect the existence of enormous quantities of dark matter, but rather the simple refusal of the universe to obey what physicists presume to be the laws of nature.

The Israeli physicist Mordehai Milgrom of the Weizmann Institute in Rehovot, Israel, proposed that approach, and for a time his idea seemed to explain the observational results without recourse to much dark matter. But to many astronomers now, Milgrom's idea seems on the verge of being disproved. Increasingly accurate observations of stellar and galactic motions at various distance scales seem to confirm existing theories of gravity.

If Einstein's theory of gravity is correct, as appears to be the case, then nonbaryonic matter—matter



Gravitational lensing can occur when light from a distant galaxy, center left, passes through a dark-matter halo around a cluster of galaxies. Here the gravitational pull of the dark matter deflects the light in such a way that an observer on Earth sees two additional images of the galaxy. The diagram is highly idealized; the distances and angles are not drawn to scale.

forever different from all known matter—has always ruled the universe. And the best hope for discovering just what form it takes now rests on finding some of it—at least a tiny amount!—here on Earth. But that poses a dilemma. The basic nature of nonbaryonic dark matter, its extreme unwillingness to engage in any interactions with ordinary particles, makes it extremely difficult to detect.

The dark-matter community, fully aware of the difficulties, has concentrated on experiments designed to find the leading dark-matter candidates. The candidates come in two categories: relatively large objects, and submicroscopic elementary particles, which would have to exist in huge quantities. The sizable dark-matter candidates

have the generic name MACHOs, short for “massive compact halo objects.” MACHOs might be black holes with masses something like that of a star; or smaller, more numerous black holes with masses similar to those of planets; or perhaps the cores of burned-out stars that collapsed but did not form black holes. Gravitational lensing can reveal MACHOs, and astronomers have even found a few with starlike masses. But the results so far imply that MACHOs cannot supply the bulk of the cosmic mass.

If so, the best hopes lie with nonbaryonic elementary particles, which exist so far only in theory. But some of the theories predicting their existence display promising elegance and symmetry, so particles are the favored dark-matter candidates. Two kinds of hypothetical particles seem the most appealing.

First is the axion, a particle named after a laundry detergent, because its hypothetical properties cleaned up a conflict between a theory known as quantum chromodynamics and certain experimental results. Each axion would have an exceedingly small mass—less than a millionth of the electron’s own tiny mass.

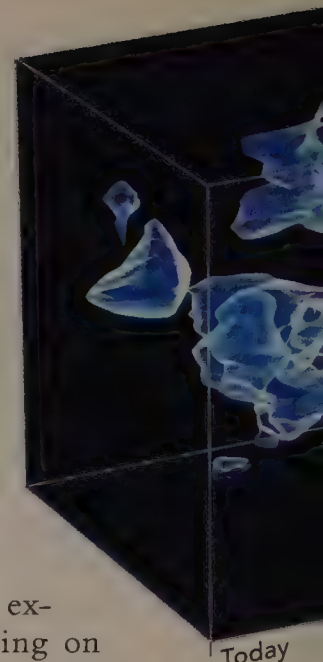
If axions do exist and throng our galaxy, they must occasionally be scattered by the magnetic fields that permeate the Milky Way. The scatterings would generate radio waves at a frequency that depends on the small (and unknown) mass of the axion. The world’s most advanced axion detector, at the Lawrence Livermore National Laboratory in California, seeks those radio waves by searching a wide band of possible frequencies with supremely sensitive amplifiers. So far, all axion searches have proven fruitless, but the search goes on.

If not axions, why not WIMPs? The name stands for “weakly interacting massive particle”—a concise description of the second leading candidate among hypothetical dark-matter particles. “Weakly interacting” means interacting mainly via the weak force, the force responsible for certain kinds of atomic “decay” and the least familiar of

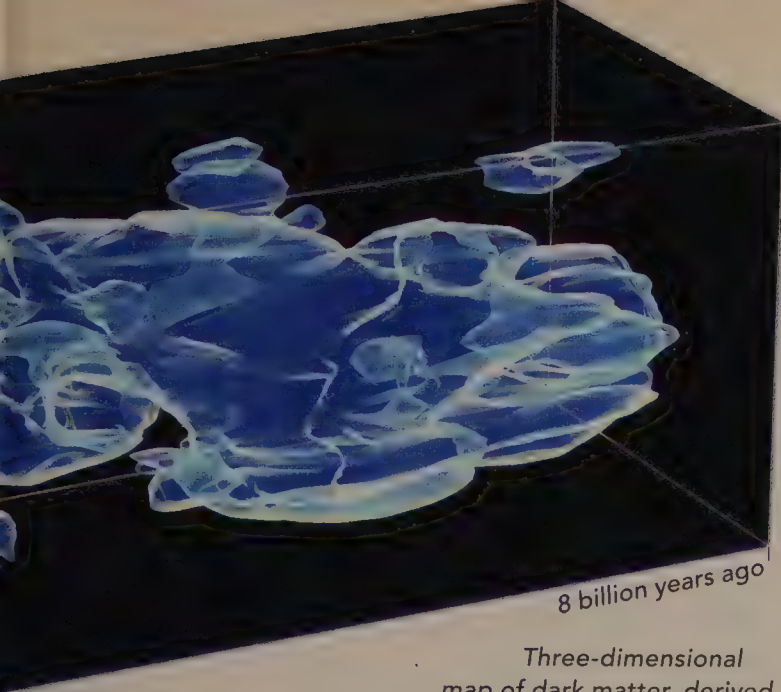
the four fundamental forces in nature. “Massive” in this context means “at least a few dozen times the mass of a proton.” (The name “MACHOs,” for dark-matter black holes, was chosen to contrast with “WIMPs,” which was proposed first.) Because WIMPs arise from the predictions within a class of persuasive theories of elementary particles called supersymmetric, many particle theorists think WIMPs exist.

To find the elusive WIMPs, experimental physicists are betting on the likelihood that, once in a blue moon, a WIMP will collide with ordinary matter. Such a collision would lead to a wimpy—as in “amazingly small”—effect in the bowels of a WIMP detector, so extraordinary measures must be taken if physicists hope to notice it. Experimenters reduce the normal atomic vibrations of the sensors within the detector as far as possible by cooling the sensors close to absolute zero. Placing the apparatus deep underground shields it from interference from less penetrating potential sources of spurious signals, such as the cosmic rays that continuously bombard the Earth.

At least half a dozen competing teams of experimenters from Europe and the United States are now operating and improving their WIMP detectors, which build on two basic designs. In the first design, the sensors are several dozen crystals, each weighing about a kilogram, made of highly purified germanium or silicon. Two detectors employ that design, one inside the Gran Sasso tunnel, nearly a mile beneath Italy’s Apennine mountains, and the other at the bottom of a decommissioned mine in northern Minnesota. If a WIMP strikes an atom in one of the crystals, the crystal should ever so slightly heat up and vibrate. So far the crystal detectors have found no WIMPs, but the crystals may well fail to provide



Attempts to find the elusive particles that form dark matter have so far yielded only hope and construction contracts.



Three-dimensional map of dark matter, derived from observations of the effects of gravitational lensing, reveals vast "isles" of dark matter that dominate the large-scale structure of the universe. The map covers a patch of sky 1.6 degrees on a side, out to 8 billion light-years from Earth. The ancient light from distant galaxies enables astronomers to reconstruct how dark matter has evolved (right to left) since early in the history of the universe.

a sufficiently large target to succeed in only a year or two of operation.

To increase their chances of registering WIMP impacts, the experimenters naturally would like to enlarge the target, but with crystal-based detectors, that poses technological difficulties. Enter the second, and newer, kind of WIMP detector, whose target is a pool of ultra-pure, liquefied inert gas. Ongoing experiments with liquefied argon or xenon detectors now operate within the Boulby mine in Yorkshire, England, and in the Gran Sasso tunnel.

Like the crystal detectors, the inert-gas detectors have yet to register a single WIMP. Nevertheless, experimenters have high hopes for success with the design, because they can scale up inert-gas detectors with relative ease. The next generation will deploy not a few kilograms but a few hundred kilograms of target material. Elena Aprile, a physicist at Columbia University who leads the attempt to find a xenon-bumping WIMP in the Gran Sasso tunnel, hopes for a sizable gain in sensitivity by the end of 2008.

In short, attempts to find the elusive particles of dark matter have so far yielded only hope and construction contracts. In more scientific language, the experimentally established upper limits on the tendency of WIMPs or axions to interact with ordinary matter have grown progressively smaller. So far those upper limits do not rule out the viability of either of these dark-matter candidates. No one can say, just yet, that axions or WIMPs do not exist

in sufficient numbers, and with enough mass per particle, to account for the bulk of the nonbaryonic dark matter.

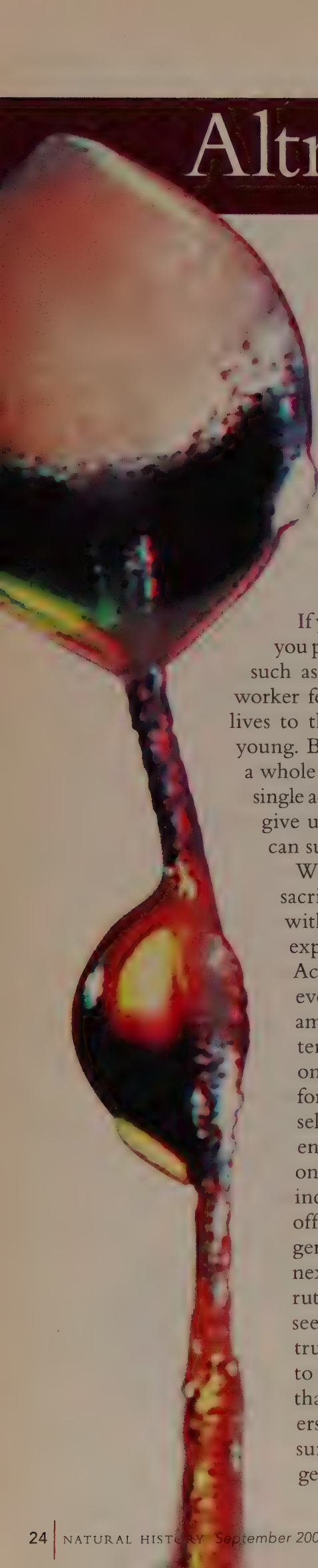
Experimenters working with both kinds of dark-matter detectors know that a formidable competitor looms on the horizon. The Large Hadron Collider (LHC), built at CERN, the European Organization for Nuclear Research, just outside Geneva, is now scheduled to begin serious operation in mid-2008. Once up and running, the LHC will be the world's biggest particle accelerator. Dug several hundred feet under the Swiss and French countryside, it will accelerate two clumps, or "beams," of particles many times around a ring more than five miles across, before smashing the two beams into each other.

Although the LHC was not designed to search for dark matter, its collisions will give birth to the most massive particles ever generated in any machine. If the LHC can verify supersymmetric particle theories, as expected, it will confirm WIMPs as real. Naturally, the builders of dark-matter detectors, currently stymied in their searches for axions and WIMPs, would like nothing better than to find the dark matter before the LHC can make its roundabout confirmation-by-implication.

They must hurry. Bernard Sadoulet, a physicist at the University of California, Berkeley, who has become the grand old man of dark-matter detection, thinks physics has a "decent chance" of ruling axions and WIMPs in or out of contention in the next five years.

And what if more sensitive experiments show that neither axions nor WIMPs can explain the dark matter? Life will go on, and so will the universe, most of it made of dark matter of unknown form, just as it is today. Inventive theorists will suggest new possibilities, and experimentally minded particle physicists will improve their detectors and their analyses. And both theorists and experimenters will continue to work in the hope that they will be the fortunate ones to resolve this fundamental cosmic mystery. Two hundred fifty years ago, the town of Whitby, in Yorkshire, produced James Cook, arguably the greatest explorer of Earth. Perhaps in the next five years the dark-matter experimenters in the Boulby mine, near Whitby, will be able to announce one of the greatest discoveries about the cosmos: the nature of dark matter. □

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Altruism among Amoebas

A person who dies so that others can escape starvation is a hero. But how can evolution explain the same behavior in a nonhuman organism whose genes are “selfish”?

By Joan E. Strassmann and David C. Queller

Can you think of a species, other than our own, in which some individuals sacrifice their own interests for the sake of others? If you're like many other nature lovers, you probably thought of the social insects, such as ants and wasps. In those species, worker females devote their long, complex lives to the service of their queen and her young. But another group takes altruism to a whole new level: the social amoebas. In a single act of self-sacrifice, certain individuals give up their lives so that other amoebas can survive and later multiply.

Why should that be puzzling? If self-sacrifice is a characteristic that persists within our own species, wouldn't you expect to find its roots deeper in nature? Actually, all the way up and down the evolutionary scale, from single-celled amoebas to human beings, the persistence of a tendency to help others at one's own expense is a conundrum for natural selection. After all, natural selection normally acts on the genetic endowments of individuals, one by one, not on groups as a whole. If an individual does not pass on its genes to offspring, for whatever reason, those genes will be that much scarcer in the next generation. The process is blind, ruthless, and competitive, and it would seem to shut the door on genes for altruism. In particular, genes that tend to produce freeloaders—individuals that take advantage of altruism in others without sharing the cost—should survive and quickly crowd out any genes for altruism. Such “cheater” genes

ought to be favored by natural selection, and spread through any population. So how can self-sacrifice be a successful strategy?

Our curiosity about that question led us to the Appalachian Mountains of Virginia, where social amoebas of the species *Dictyostelium discoideum* had been collected before. *Dictyostelium* amoebas feed on bacteria, so we asked ourselves where bacteria might be most abundant. And sure enough, we discovered a “fruiting body” of social amoebas on the very first pile of not-so-fresh deer pellets we examined under a field microscope. A tiny golden orb, held up by a slender white stalk, seemed to float a millimeter or so above its circular base, glued onto the dung. The light from our microscope made it gleam. The sight was both exotic and commonplace: Hundreds of biologists around the world work on this social amoeba in the laboratory. But we were apparently the first to see a *D. discoideum* fruiting body in its natural habitat [see photographs on this and opposite pages].

Our discovery marked both a departure and a continuity in our careers as biologists. Early on, we each developed a deep interest in biological altruism, inspired by the work of the English evolutionary biologist William D. Hamilton. In the 1960s Hamilton argued that altruistic behavior could evolve if the genes responsible for that behavior benefited relatives that shared copies of the same altruistic genes. (Relatives are more or less likely to share a gene depending on how closely or distantly the individuals are related.)

Hamilton pointed out that an individual can pass on altruism genes even if it has no offspring—by helping a relative pass on copies of genes they share. If that helping, or altruistic, behavior is more effective at passing on the individual's genes than some alternate behavior, Hamilton reasoned, the genes for altruism are likely to propagate, through a process

called kin selection. He argued, for instance, that the unusual three-quarters relatedness among ant sisters could help explain their altruism. Richard Dawkins, an evolutionary biologist at the University of Oxford, later popularized Hamilton's idea in his best seller, *The Selfish Gene*.

With our mutual interest in altruism, it was natural for us to collaborate. We spent a quarter century studying the social behavior of wasps in places such as the olive groves of Tuscany and the rain forests of Venezuela. Yet having become experts in the habits and habitats of wasps, we decided to switch to social amoebas, a group of organisms we knew little about. But what was so compelling about these tiny creatures that, in midcareers, we veered onto an entirely new path that soon had us genuflecting before dung in the Appalachians?

What we saw was the chance to remedy a major deficit in the study of selfishness and altruism. The selfish-gene account of altruism has been pursued largely without knowing anything about the actual genes that underlie social behavior. The social amoeba *D. discoideum* had the advantage of being a model laboratory organism, cultured in great numbers and studied by a large community of biologists. The organism's genome has been sequenced. Investigators have developed a superb toolkit for manipulating its DNA. Experimenters can selectively knock out, or inactivate, any genes of interest, or even replace them. In social amoebas we could study real selfish genes.

Social amoebas are also known as "cellular slime molds," but the name is a misnomer. The creatures are not slimy, and they are not molds. They comprise a hundred or so species belonging to the Amoebozoa, an ancient taxon which arose perhaps a billion years ago when it split off from the evolutionary branch that later gave rise to animals and fungi. Thus the cellular slime molds are no more closely related to any fungal mold than they are to your Aunt Alice.

Most of the time social amoebas do what most people think amoebas do: they move through soil by extending their pseudopods, or amorphous "feet" of protoplasm, and engulf prey along the way. We think of them as slow-motion cheetahs on the microbial equivalent of the African plains, feasting on bacteria, the even slower equivalent of gazelles. Each unicellular amoeba eats, grows, and



Tens of thousands of individual social amoebas of the species *Dictyostelium discoideum* join together to form a fruiting body that is just visible to the naked eye. The fruiting body is the hairlike structure with what appears to be a shiny droplet at its top, in the center of the photograph above, magnified 26x; a closeup of the "droplet" is shown on the opposite page, magnified 1,100x. The droplet is made up of many fertile spores. The "hair," or stalk, is made up of individual amoebas that died after producing strong cellulose walls. The altruistic self-sacrifice of the amoebas in the stalk raises the spores to a more prominent position, increasing the likelihood that the spores will be dispersed and survive.

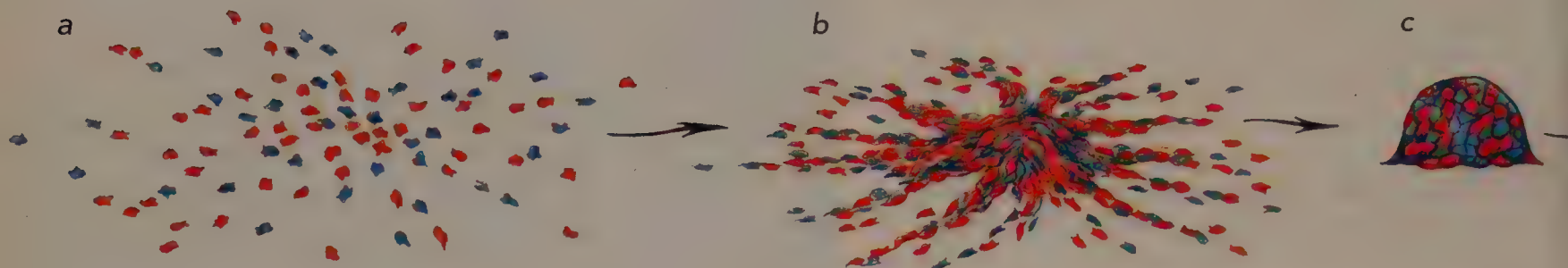
then, as every schoolchild knows, splits down the middle to make two genetically identical cells.

Social amoebas live nearly everywhere there is soil, decaying vegetable matter, and a little bit of moisture. On the abundant bacteria in a deer pellet, social amoebas can persist through many generations of eating and dividing. In that stage of their lives they are not even particularly social; still, they constantly send out and receive signals that keep them informed about the presence and abundance of others of their kind, as well as about any nearby herds of bacteria.

Social life gets interesting only when food gets scarce. When *D. discoideum* amoebas begin to starve, they release a small molecule known as cAMP, which attracts other amoebas. Chains of hundreds of amoebas move up the cAMP concentration



Solitary, unicellular *D. discoideum* amoebas of two genetically distinct strains, or clones (red, blue), begin to aggregate when food is scarce (a). Forming long chains (b), the two clones move toward a common, central area, where a visible mound arises (c). The amoebas then elongate into a "slug" (d) that lifts its "head" and crawls toward heat and light (e). Amoebas in the front 20 percent of the slug later form a stalk and die; the blue clone is cheating by not sending its fair share to the front. When the slug reaches a suitable place for producing



gradient and merge into a mound made up of tens of thousands of individuals [see illustration above]. The minute but now visible mound elongates into a "slug," which crawls as one multicellular body across the forest floor toward heat and light, and away from ammonia, a common waste product.

When the slug finds a suitable place, it stops and reorganizes. The individual amoebas that formed the front 20 percent of the slug arrange themselves into a stalk, laying down tough cell walls of cellulose, just as plants do. Individuals from the back 80 percent flow up the stalk, then reorganize at the top into a ball of hardy spores—the orb we spotted with our field microscope in Virginia. The amoebas that form the stalk die, but the spores, elevated by the self-sacrificing stalk amoebas, are thereby put in a good position to stick to passing insects or other organisms that can carry them to "greener pastures," richer in bacterial food.

The multicellular fruiting body is not unusual in being cooperative. After all, the cells in your own body cooperate as well, altruistically doing their jobs and dying without getting into the next generation. But that altruism is easy to understand because your body is one big clone of genetically identical cells, derived from the division of a single fertilized egg cell. A gene that causes a liver cell to cooperate dies when the liver cell dies, but identical copies of the gene are passed on through sperm and eggs. The genes in liver cells destined to die would gain no evolutionary advantage by, say, sneaking into the gonads and getting into the next generation.

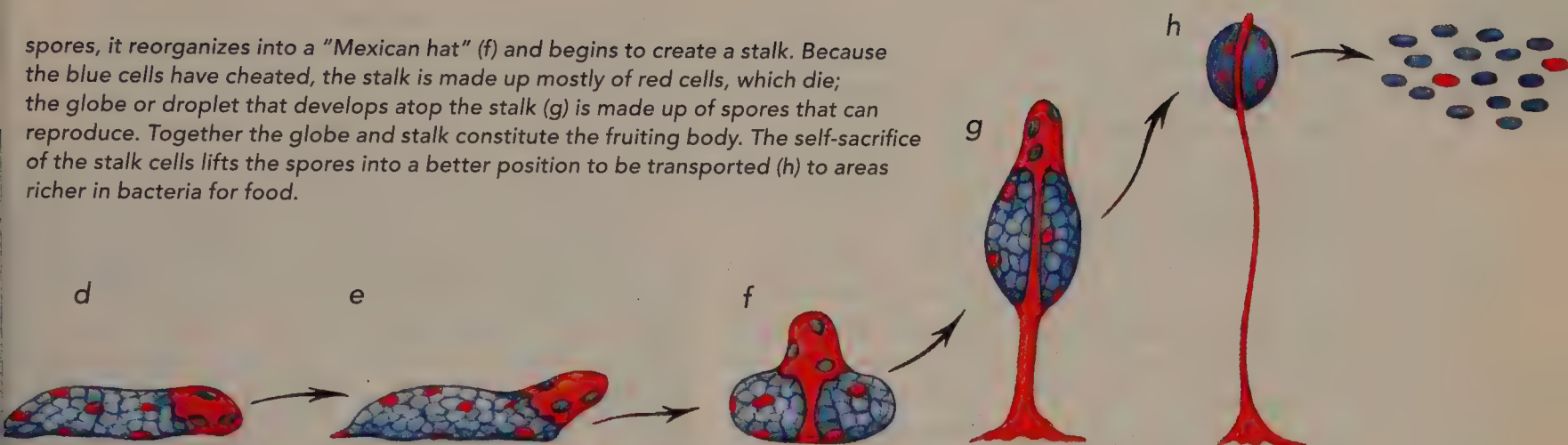
What is unusual about the *D. discoideum* slug and fruiting body is that they form from dispersed cells that aggregate even though not all of them are

genetically identical. Such an aggregate is called a chimera, and in a chimera, one genetic type can gain an evolutionary advantage by outcompeting the others. For example, a clone of genetically identical *D. discoideum* cells can leave more descendants if it cheats and makes more than its share of spores, forcing cells of other clones into the doomed stalk. We wanted to understand how altruism can be a successful strategy in the face of such cheating.

Our switch from wasp studies to social-amoeba research paralleled, in a curious way, the behavior of the amoebas themselves. We were accustomed to the rather solitary mode of field biology, but to get to greener research pastures, we had to work more cooperatively with the larger *Dictyostelium* community. Not only were we switching research organisms, but we were also switching scale, from macroscopic to microscopic, and switching to work that would involve the unfamiliar areas of cell biology and molecular genetics. Would we find the "dicty" community welcoming and cooperative, or skeptical and distrustful of admittedly ignorant outsiders like us?

We made our first efforts to find out via the Internet. Most dicty investigators are signed up for a listserv, and so we began to "send out signals" by posting elementary questions there, which were patiently answered by leaders in *Dictyostelium* molecular biology. When we first made contact, we did not yet know whether genetically distinct clones grouped together. But unfortunately, our new colleagues could shed no real light on that question or some of the others we were keenest to answer: If genetically distinct clones group together, do individuals in each clone get an equal chance to become fertile

spores, it reorganizes into a "Mexican hat" (f) and begins to create a stalk. Because the blue cells have cheated, the stalk is made up mostly of red cells, which die; the globe or droplet that develops atop the stalk (g) is made up of spores that can reproduce. Together the globe and stalk constitute the fruiting body. The self-sacrifice of the stalk cells lifts the spores into a better position to be transported (h) to areas richer in bacteria for food.



spores, or is one clone unfairly consigned to serving primarily as altruistic stalk? Can social interactions among amoebas be studied in the wild?

Instead of answers, one of the dicty biologists, Dennis Welker of Utah State University in Logan, gave us something far more valuable: a genetically diverse collection of wild-caught clones. Such a collection might not seem special, since hundreds of molecular biologists work on *D. discoideum*. But a molecular biologist almost always works with the descendants of a single clone, which has been bred to behave well in the laboratory. To us a single clone was of little use, because one would expect a clone to behave purely cooperatively, for the same reasons the cells in the human body do.

The wild clones enabled us to run some simple tests to see whether cooperation among the amoebas was vulnerable to cheating. We mixed cells of two clones together, then examined the resulting fruiting bodies for the presence of both. Sure enough, each fruiting body included cells from both clones. Yet in some pairs of clones, one of the clones cheated by contributing disproportionately to the spores.

If this earliest work had indicated that *D. discoideum* sorted by clone—as we later found to be true of its relative *D. purpureum* [see photograph at right], we might not have pursued the study of *Dictyostelium* further. But the mixing and cheating confirmed that the aggregate is a complex social system rather than just another genetically uniform multicellular organism.

The very existence of cheating suggests that individuals can distinguish their clone-mates from unrelated clones. Members of our laboratory, led by Kevin Foster, a postdoctoral investigator, cor-

roborated that hunch experimentally by showing that chimeras behave differently from pure clones. Foster's team mixed amoebas from two, five, or ten distinct clones, and compared them to pure clones in their ability to cross a Petri plate. Taking advantage of their attraction to light, we covered the plates with dark paper, leaving a pinhole at the opposite end from where we put down the cells. The amoebas formed slugs and moved across the plate toward the light from the pinholes. The pure clonal slugs traveled farther than chimeric ones did before stopping and forming fruiting bodies.

Why are those results consistent with the idea



Social amoebas of the species *Dictyostelium purpureum* form fruiting bodies in the laboratory primarily with clone-mates. Although two clones of *D. purpureum* may aggregate during a collective migration, they later separate into two fruiting bodies. The image is magnified 32x.



that amoebas can distinguish clone-mates from unrelated clones in chimeras? We suspect that as the clones in a mixed slug compete to stay at the rear, where the spores will develop, the mixed slug as a whole moves forward more slowly than a slug made up of amoebas from a single clone.

We have also identified a different and unusual kind of recognition among *D. discoideum*. Hamilton noted that, in principle, recognition could be based not on overall kinship, but on the sharing of a single gene. Such a gene, he argued, would have to code for three things: a trait, the recognition of that trait in another individual, and altruism toward others with that trait. Dawkins whimsically compared such hypothetical genes to men with green beards who recognized other men with green beards and behaved altruistically toward them; he called them greenbeard genes. Most biologists, however, thought that such recognition was probably too complex to exist in nature: how could a single gene code for all three things?

Yet in the literature on *D. discoideum* we found a gene called *csaA*, for “contact site a,” that seemed to qualify. The gene codes for a cell-adhesion protein that sticks out of the cell membrane and binds to identical cell-adhesion proteins protruding from other cells. The binding of like to like satisfies the first two requirements of a greenbeard gene: *csaA* codes for a trait as well as the recognition of that trait in others. But what about the altruism part?

To find out, we contacted Salvatore Bozzaro, a molecular biologist at the University of Turin in Italy, who had studied the gene. Bozzaro’s group worked with a strain of *D. discoideum* in which the *csaA* gene was knocked out, and so his strain of amoebas lacked the adhesion protein. What would happen, we wondered, if we mixed the two otherwise identical strains, with and without *csaA*, fifty-fifty in a Petri plate? Would one of them act altruistically? Would the other one cheat?

It turned out that the knockout is a cheater—it contributes more than its share to spore tissues. The strain with intact *csaA*, known as the wild-type strain (so called because it is the typical form), ended up in the stalk. Hence in that mixture the wild-type amoebas are the more altruistic ones.

But there is more to the story. When we placed the knockout and the wild type together on the rough natural surface of soil, the weaker adhesion of the knockouts caused them to get left behind when other amoebas began to aggregate. In contrast, the wild types tended to bind to each other and pull each other into the aggregation. Thus the greenbeard recognition by the *csaA* gene ensures that the sub-

sequent altruism of the amoebas that carry the gene only benefits other amoebas that also carry the gene. The *csaA* gene is the only known example so far of a single greenbeard gene that can control altruistic behavior toward other genes of the same kind.

As it happens, the *csaA* gene is carried by all *D. discoideum* individuals we have examined so far. Hence it does not currently fully function as a greenbeard gene, because it is useless as a way to discriminate degrees of kinship within the species. But when it first arose, it could have survived as a minority gene for several generations, before it swept through the species as a result of the way it recognized and benefited itself. (It can, of course, discriminate against the rare mutants that lose the gene.) We suspect that there are other genes that do function as recognition genes. Such a gene would have to be highly variable in the species and would probably code for a molecule that protrudes from the cell membrane. The search is on for such molecules.

We had another good reason to suspect that social amoebas can identify and thereby help their close kin. The spores that aggregated on any given fruiting body we collected in the wild usually belonged to the same clone. Some mixing took place, but on average the amoebas in wild fruiting bodies were very close kin, closer than the workers in colonies of social insects.

We do not know precisely why such close kinship is the rule, but it is important for controlling cheaters. In the laboratory of Richard Kessin, a cell biologist at Columbia University, workers isolated a single-gene mutant that cheats. The cheater was highly effective in our experimental mixtures. It contributed hardly any cells to the stalk at all and instead ended up almost entirely in the spores. But the cheating, from a wider perspective, came at a high price. The cheater, on its own, cannot assemble into a viable fruiting body, and so it cannot propagate its spores. It reproduces only by mixing and forming fruiting bodies with a non-mutant strain of amoebas; in those mixed fruiting bodies, however, the presence of the mutant also lowers the total spore production. Yet despite the low spore production, the mutant can still spread in populations of mixed fruiting bodies because it cheats.

In the wild, however, relatedness is high; most



fruiting bodies form from a single clone. But for the mutant, being excluded from mixing would be disastrous; it would simply fail to produce spores. We therefore predicted that cheaters whose reproduction depends on forming mixed aggregates with other amoeba strains would not be present in the wild. Our



Aggregations of *D. discoideum* are pictured in the Mexican-hat stage, though some of them are beginning to elongate. The image is magnified 25x.

subsequent searches confirmed that prediction, suggesting that high relatedness does play an important role in limiting cheaters in nature.

Another important collaboration for us began in 2000, when we first met Adam Kuspa and Gad Shaulsky of the Baylor College of Medicine in Houston, Texas. Their expertise in genomics and cell and molecular biology seemed the perfect complement to ours in evolutionary biology and behavior. Some of the first results of our collaboration were initiated by Christopher R. L. Thompson and Foster, then postdoctoral investigators in our laboratories.

One way aggregating cells become altruistic stalk cells is by responding to a small molecule called DIF, or differentiation inducing factor. (Intriguingly, DIF seems to be produced by better-fed cells, and it induces weaker cells to become stalk. So perhaps the stalk cells are coerced into becoming stalk and are less altruistic than we thought.)

In any case, Thompson had identified a gene he called *dimA*, which, when knocked out, causes its bearer to ignore the DIF signal. We reasoned that the *dimA* knockout would be a cheater. Sure enough, when we mixed the knockout with wild-type cells, the knockout was overrepresented among the spore-forming cells at the slug stage. To our great surprise, though, when the spores developed, the knockout was underrepresented compared to the wild type. That told us the *dimA* gene must have a second function, besides recognizing DIF signals, that is important to slug-stage amoebas for transforming them into spores. That second unknown function probably evolved first, whereas receiving DIF signals, a cooperative social function, likely evolved later.

Notice that piggybacking the cooperative social function on a gene that controls another essential function is a good way to defeat cheating. A cheater that simply dropped the gene for responding to a signal such as DIF would also lose control of the second, essential function. The cheater would not survive. Building cooperative functions out of otherwise essential pathways may turn out to be a general way that many organisms control cheating.

Our stories about *csaA* and *dimA*, two genes important to cooperative social functions in *D. discoideum*, offer a glimpse of what might be learned via the genetic approach about the evolutionary benefits, and costs, of cooperation and conflict. Of course human cooperation is more complex; it often depends on reciprocation. Our own scientific experience is instructive. Our molecular biology colleagues from the dicty community have helped us learn more about evolution. But we also think our experience as evolutionary biologists brings a fresh perspective to genetics, and we hope to repay our new colleagues in their preferred currency, by illuminating gene function.

In conventional genetic studies, all the genes involved in multicellularity are studied in a single clone. Given the potential for conflict between clones, we think that is akin to studying the function of an army by watching it in peacetime. Parades and pushups give little idea of an army's actual purpose. Likewise, if social amoebas have cheater genes, the function of such genes may be impossible to discern until we examine them in the context in which they evolved: in competition with other clones. □

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Rendezvous at Red Rock

Nestled in a dry landscape, an Oklahoma canyon harbors a lush woods.

By Robert H. Mohlenbrock

Travelers speeding along Interstate 40 between Oklahoma City and Amarillo, Texas, may not realize that the mostly flat and sparsely vegetated terrain they see on both sides of the highway is pierced here and there by colorful canyons. One of those gems is Red Rock Canyon, just a five-mile detour off exit 101. From the exit, follow U.S. Highway 281 south through the town of Hinton, Oklahoma, and take the turnoff to Red Rock Canyon State Park. The road leads to a small visitor center and then switchbacks down into a narrow canyon whose sheer, red sandstone cliffs rise fifty feet or more above the canyon floor.

Red Rock Canyon reflects the region's complex geological history. About 360 million years ago a shallow sea extended across what is now the western half of the southern United States.

Ancient sections of the Rocky Mountains bordered its western shores, while the Ouachitas and the Ozarks stood at the far eastern edge. Marine sediments, together with mud and sand washed down by rivers, formed deposits on the seafloor. From time to time as the sea contracted, some sand deposits in the river deltas were exposed to the air and became windblown, covering other kinds of exposed deposits. By

215 million years ago the sea receded, and the various sediments consolidated into layers of dolomite, sandstone, shale, and other rocks.

Red Rock Canyon formed during the Pleistocene, the epoch of intermittent ice ages that lasted from about 1.8 million until 10,000 years ago. Although the glaciers never penetrated as far south as Oklahoma, streams from the north cut channels in



VISITOR INFORMATION

Red Rock Canyon State Park
P. O. Box 502
Hinton, OK 73047
405-542-6344
www.oklahomaparks.com



Spore-bearing structures arise on stems of rough horsetail, *Equisetum hyemale*.

the rocks, particularly during the interglacial periods, when melting ice increased their flow. The canyon may have formed where it did because a stream that was gradually etching its bed in sandstone encountered a local, underlying deposit of shale. Because shale is softer than sandstone, the stream would have dug into it more deeply, creating a waterfall off the sandstone rim bordering the hollowed-out area. As erosion progressed at the rim, the waterfall would have slowly migrated upstream, lengthening the canyon.

Today Red Rock Canyon is roughly two and a half miles long and between eighty and 750 feet wide. In much of the canyon, where sandstone once overlay shale, the waters undercut the sandstone to form rock overhangs and other contours, including an eye-catching one called Balanced Rock. No longer scoured

Mesic woods Some of the largest trees are Kentucky coffee trees. Also common are black locust, bur oak, eastern redbud, netleaf hackberry, red mulberry, slippery elm, southern sugar maple, western soapberry,

and woolly buckthorn. Locally the southern sugar maple is called the Caddo maple. Although it is not scientifically named as a separate variety, it has a distinctive characteristic: the undersides of the leaves are a chalky white

instead of the usual pale green. Among the shrubs are common hop tree, red buckeye, roughleaf dogwood, and wild plum. Vines are abundant, including American bittersweet, American hog peanut, bristly greenbrier,

common moonseed, eastern poison ivy, roundleaf greenbrier, summer grape, trumpet creeper, and Virginia creeper.

Streamside Common trees are American elm, box elder, eastern cottonwood, green

by heavy flows, the bedrock floor of the canyon is covered to a depth of about forty feet with loose sand and mud carried in from the surrounding area by streams.

The Rough Horsetail Trail—four-tenths of a mile round trip—offers visitors a good introduction to Red Rock Canyon State Park and the canyon's forest vegetation. It follows a meandering stream through a mesic (moist) woods at the foot of red cliffs. The trail is named for *Equisetum hyemale*, or scouring rush horsetail, often called rough horsetail, a species that grows abundantly along the first part of the trail. It belongs to an ancient order of spore-producing plants known as the Equisetales, which were much more prominent at the time dinosaurs

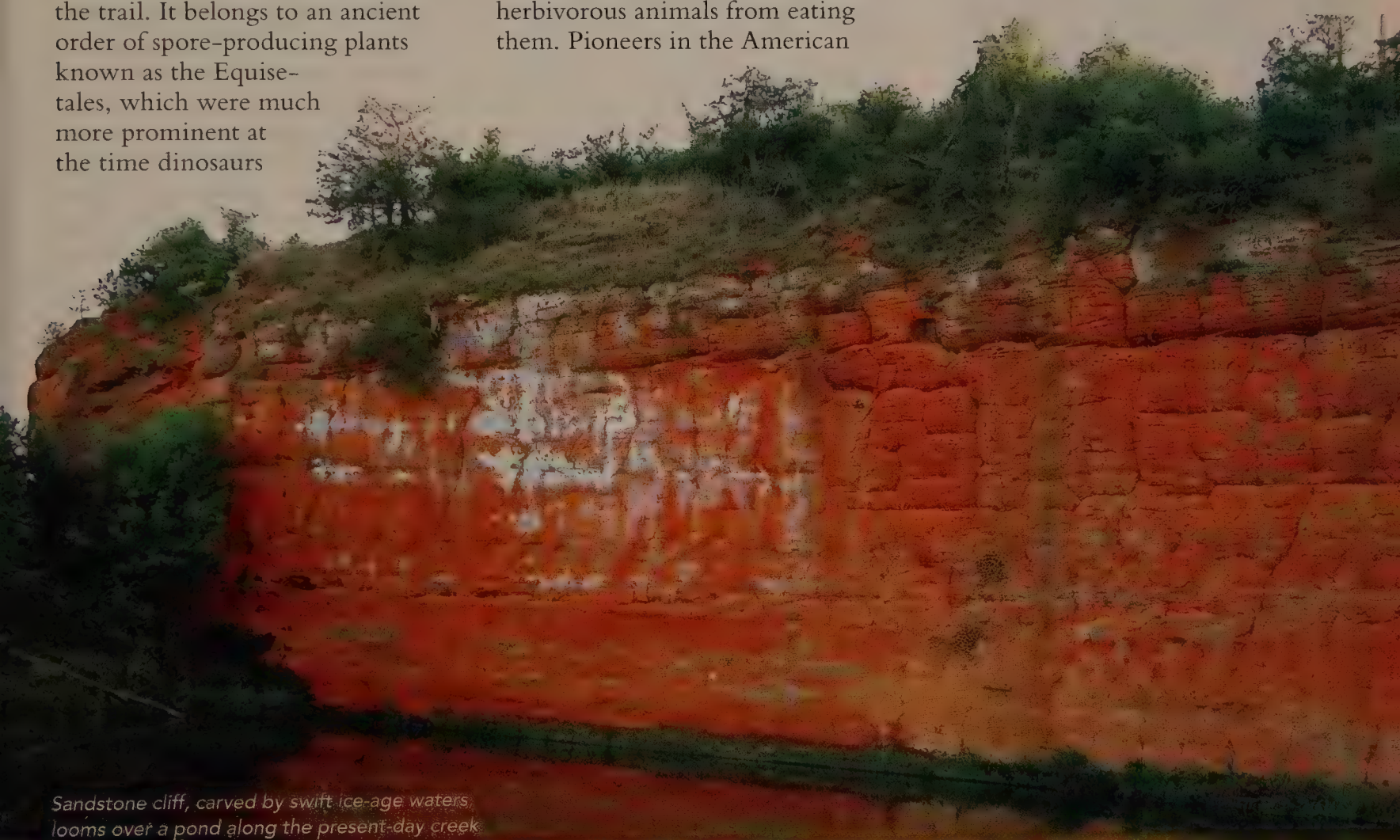
roamed the earth. Fossil records show that some members of the group grew forty feet tall and had trunks more than a foot in diameter. Today the order comprises only fifteen species, all in the genus *Equisetum*, and the tallest of them grows just ten feet high.

The fifteen extant species, ten of which occur in the U.S., all have jointed, hollow, green stems above the ground as well as rhizomes, or horizontal underground stems. The stem tissue can store deposits of silicon dioxide (silica) that the plant has taken up from the soil. The crystalline silica gives the stems a rasping texture, which discourages herbivorous animals from eating them. Pioneers in the American

West would break the stems apart at their joints to make short pieces, tie them together, and use them as scouring brushes for pots and pans.

The Rough Horsetail Trail ends in a box canyon where, after a heavy rain, you will find yourself at the bottom of a twenty-five-foot-high waterfall. Other, moderately steep trails lead from the base of the canyon to its rim. There one can observe the drier habitat at the top of the cliffs.

ROBERT H. MOHLENBROCK is distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.



Sandstone cliff, carved by swift ice-age waters, looms over a pond along the present-day creek

ash, and Shumard oak. Small trees and shrubs include common buttonbush and elderberry. A pretty spring flower is Missouri violet, with blue flowers and arrowhead-shaped leaves. Watercress grows in the clearer streams. A plant to

avoid is woodland nettle, with stinging hairs on its leaves, stems, and flowering stalks.

Cliff-top Blackjack oak, eastern red cedar, and post oak are the most common trees, but chinquapin oak and

smooth sumac are also present. Coralberry and other shrubs occur here and there, but Adam's needle and prickly pear are more typical. Grasses such as broomsedge bluestem, Indian grass, little bluestem, and switch grass

make up much of the vegetation. Most of the wildflowers, including black-eyed Susan, eastern purple coneflower, flowering spurge, green milkweed, and hairy false golden aster, bloom in late summer and in the fall.

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REVIEW

Literary Gould

By Laurence A. Marschall

*The Richness of Life:
The Essential Stephen Jay Gould*
edited by Steven Rose;
Foreword by Oliver Sacks
Norton; \$35.00

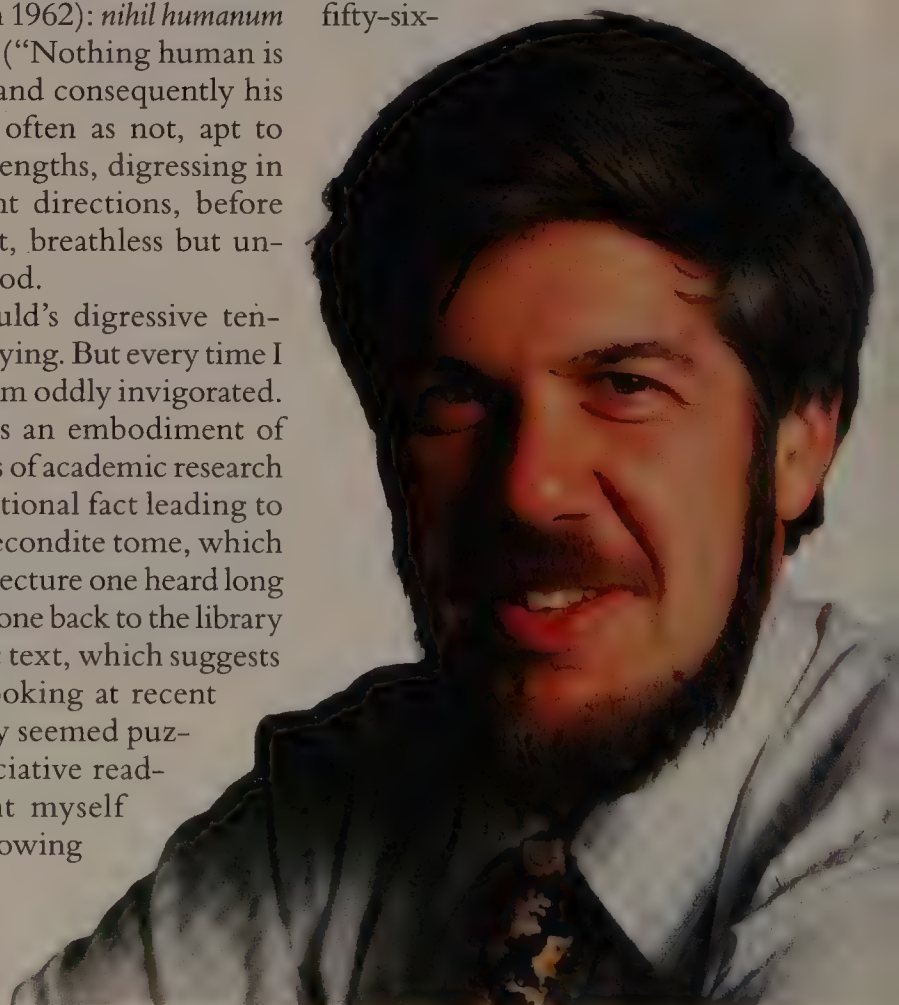
Stephen Jay Gould's 300th and last Essay appeared in the pages of this magazine in January 2001, and there has been, frankly, no one to replace him. Gould was a master of the bon mot, the short, pithy phrasing that summarized a complex scientific idea in a few choice words. But he was also a man of many passions—baseball, Beethoven, biology, books—a polymath whose motto might have been the famous line from the second century B.C. Roman playwright Terence (a catchphrase of the liberal arts I recall first seeing in a mosaic in the foyer of Willard Straight Hall on the Cornell Campus when I was a freshman in 1962): *nihil humanum a me alienum puto* ("Nothing human is alien to me")—and consequently his sentences were, often as not, apt to run on to great lengths, digressing in a dozen different directions, before coming to a halt, breathless but unbroken, at a period.

To some, Gould's digressive tendency could be trying. But every time I read his work, I am oddly invigorated. Each essay seems an embodiment of the joyful process of academic research itself: an observational fact leading to a reference in a recondite tome, which brings to mind a lecture one heard long ago, which sends one back to the library to reread a classic text, which suggests a new way of looking at recent facts that initially seemed puzzling. For appreciative readers, and I count myself among them, following

the thread of a Gould essay is a bit like tracing the tree of evolution: it branches unexpectedly, and one is never clear where it will end up or what novel realization will appear along the way.

Steven Rose, a biologist at the Open University in the U. K., clearly shares my appreciation of Gould, and so he must have found it daunting to select a representative sample of Gouldiana. Gould's work as a whole can be taken as a continuing argument for the power of a simple process—evolution—to create the profusion of forms that life has taken. But Gould engaged that theme in such a large number of variations that surely Rose was forced to arbitrarily omit immense amounts of worthy material.

What Rose has chosen, though, is bound to please Gould's fans. There are, of course, the wonderful baseball articles, such as his examination of Joe DiMaggio's incredible fifty-six-



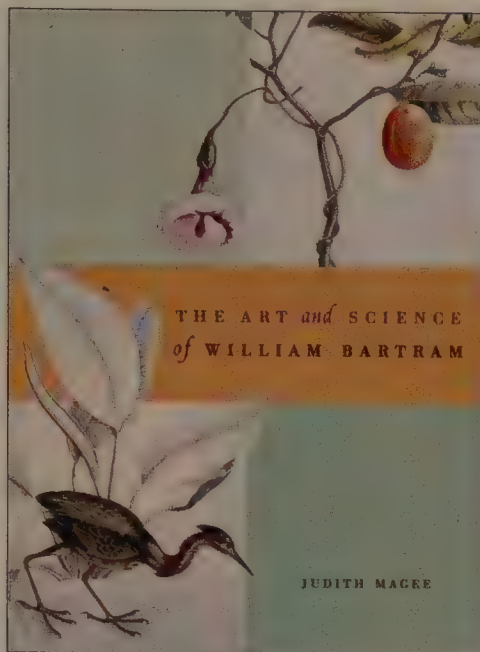
Stephen Jay
Gould in 1982,
at the age of 41

game hitting streak in 1941. In typical Gould fashion, his meditation on Joltin' Joe's achievement is not only a chance to show how remarkable it was, but also to call for a sense of humility in confronting the transience of species and the fragility of life: "The history of a species, or any natural phenomenon that requires unbroken continuity in a world of trouble, works like a batting streak."

Classic Gould themes are present throughout. Explicating the mechanism of evolution, of course, is central. Rose includes a long selection from Gould's magnum opus, *The Structure of Evolutionary Theory*, along with Gould's well-known essay, "The Spandrels of San Marco," about how seemingly purposeful results can emerge as by-products of random processes. Wonderful pieces on figures in the history of science have also found their place here. Paul Broca, for instance, the nineteenth-century surgeon who popularized the field of "craniology," the study of the size and shape of skulls, expected his work would lead to a science of intelligence. But as Gould notes, Broca even in his heyday had trouble explaining why a study revealed the brains of murderers and thieves to be statistically larger than those of honest men, or why the brain of the great mathematician Karl Friedrich Gauss weighed only slightly more than average.

For readers who missed Gould's quarter century of essays in *Natural History*, this anthology cannot be recommended highly enough—it's a great way to make the acquaintance of a fine teacher and a fascinating writer. For those of us who already know his works, it's like an old family scrapbook, reminding us how much we miss a man who enjoyed life so fully, and who enriched our own lives in so many ways.

LAURENCE A. MARSCHALL, author of *The Supernova Story*, is W.K.T. Sahn Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.



THE ART AND SCIENCE OF WILLIAM BARTRAM

Judith Magee

Co-published with the Natural History Museum, London

William Bartram's love of nature led him to explore the environs of the American Southeast between 1773 and 1777. Here he collected plants and seeds, kept a journal of his observations of nature, and made drawings of the plants and animals he encountered. The completed drawings were sent to his patron in London, and these make up the bulk of the collection held at London's Natural History Museum.

The Art and Science of William Bartram brings together, for the first time, all sixty-eight drawings by Bartram held at the Natural History Museum, along with works by some of the most well-known natural history artists of the eighteenth and nineteenth centuries. The volume explores Bartram's writings and artwork and reveals how influential he was in American science of the period.

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That Gnawing Feeling

By Robert Anderson

Recently I've been replacing my deck, which was devoured by colonies of drywood termites (as distinct from subterranean and other kinds). With termite damage and control costing U.S. homeowners and businesses billions of dollars a year, I know I'm not alone. On the Internet you not only can find advice on coping with these home wreckers, but also learn about the biology of the world's 2,761 termite species. Please visit the *Natural History* Web site (www.naturalhistorymag.com), to explore my review of termite sites. You'll discover that the destructive pests are not all bad.

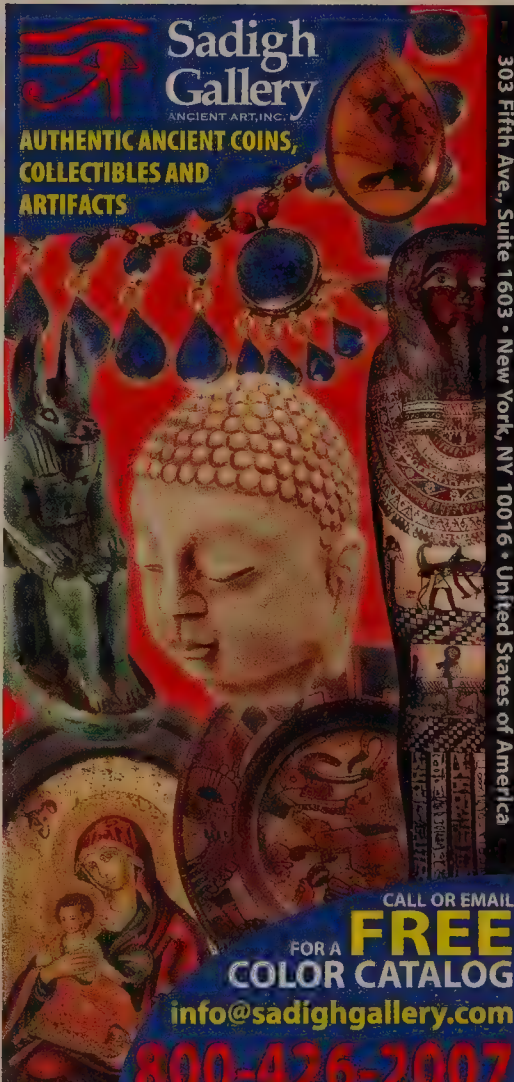
ROBERT ANDERSON is a freelance science writer living in Los Angeles.



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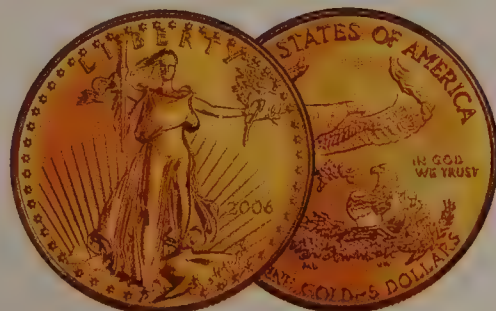
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Surprise Package

A supermassive black hole may lie at the heart of an intergalactic collision.

By Charles Liu

Galaxies come in a bewildering variety of shapes and sizes. Spiral and elliptical galaxies are the two best known. The spiral is essentially a disc, and its arms are regions of the disk brightened by hot young stars; the elliptical is shaped like a rugby ball. The so-called peculiar galaxies are tougher to classify, mainly because they're, well, peculiar. Wispy tails, loops, bridges, and other long and short aggregations of stars gather within those galaxies and stretch out beyond them. Beginning in the 1930s, when the variety of galaxy shapes first became evident, astronomers argued about how such peculiarities came about. Some hypothesized that they were shaped by the gravity of a neighboring galaxy, but there was no hard evidence to back that up.

The answer came when a new technology was added to the astronomer's toolkit: the computer. In 1972 the astrophysicists Alar Toomre of the Massachusetts Institute of Technology and his brother Juri Toomre, then at New York University and the Goddard Institute for Space Studies in New York City, published an article that launched modern computational astrophysics. "Toomre and Toomre" (as the paper is commonly known) showed that the wide variety of strange-looking structures could be accounted for entirely by the gravitational tides that arise when two galaxies collide.

It's important to emphasize that as galaxies crash into one another, the individual stars that make them up remain generally unscathed. That's

because the stars within each galaxy are scattered so far apart that they simply stream past one another, like cosmic bees in two colliding swarms. But the gravitational chaos of the collision throws stars off course, disrupting the elegant spiral or elliptical galactic shapes.

Five years after "Toomre and Toomre" appeared, Alar Toomre pondered what would happen when two colliding galaxies merged into one. He proposed that the merging system might follow an evolutionary sequence that would just about run the gamut of galaxy peculiarities, until it finally settled into a large elliptical. In a 1977 paper, Toomre sketched images of eleven real galaxies, placing them in an order that illustrated the merging process from the beginning nearly to the end. In its essentials, the so-called Toomre sequence has since been confirmed by computer simulations on machines many millions of times more powerful than the ones available back in the 1970s.

Of course, we astronomers can run all the computer simulations we want. But if, in the end, we can't connect the results of our virtual experiments with real galaxies, we haven't actually learned anything. And for many years, one kind of galactic formation that showed up in the simulations was conspicuously absent from the lineup of real galaxies: the shape of two galaxies at the very end of a simulated collision, the last transition between "still merging" and "all done merging."

That changed in 1991. William R. Oegerle, then at the Space Tele-



Computer simulation depicts how our Milky Way galaxy might merge with the Andromeda galaxy. Beginning some 3 billion years in the future (top), the two disk-shaped galaxies approach each other—the Milky Way edge on and Andromeda in the foreground. As they collide, tidal forces rip streams of stars and gas out of the main disks and fling them far into intergalactic space (middle three images). More than a billion years after initial contact (bottom image, above), the two galaxies have essentially merged into one. The simulation was made by John J. Dubinski, an astrophysicist at the University of Toronto.

scope Science Institute in Baltimore, Maryland, and his colleagues discovered a galaxy that seemed to fit the description of the wanted object. They called it G515; and as far as anyone knows, it is the only object out of the 100 million or so galaxies within 1.5 billion light years of Earth that looks exactly like a nearly completed galaxy collision.

When I read about that rare find, I resolved to learn all I could about it. It took me a while, but now, sixteen years later, I've led a new study of G515. Our study confirms what the simulations had predicted: that the system is just about to finish merging, a billion years after a collision started. But as so often happens in science, the work to resolve the initial question has opened up a new and perhaps even more intriguing mystery. At its heart, G515 may harbor a supermassive black hole.

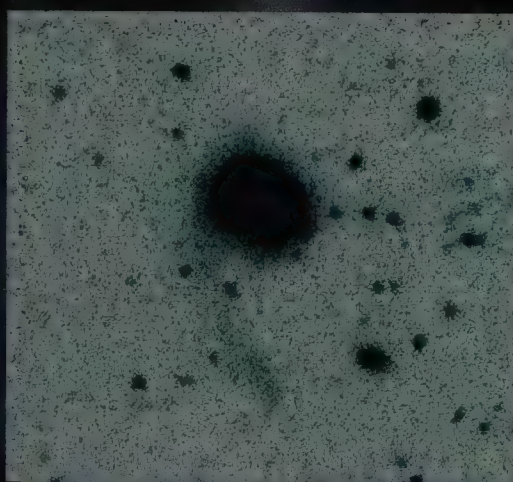
Our suspicions about a black hole arose, in a roundabout way, from our attempts to pin down the age of G515. What made us so sure that G515 was the result of a collision that began a billion years ago?

Real collisions between galaxies are far too slow for people to observe. Thanks to ever more powerful computer simulations, however, we astronomers can make pretty good predictions about what merging galaxy systems would look like at any given stage of the process. From basic physics, our knowledge of galaxy sizes and shapes, and lots of computer time, we now know that when galaxy collisions lead to mergers, it takes about a billion years to consummate the union; and we can calculate what any given merging system might look like after 100 million years, 200 million years, and so on.

Once we have run a simulation, we search the vast cosmic firmament for a galaxy system that looks like it has reached one of the simulated stages. Working backward, that gives us a good idea of how much time has elapsed since the collision

began. But we can't stop there; we need an independent check. It's like guessing the age of a random woman in Times Square on New Year's Eve based solely on a sense of what people look like as they age. You can't be sure you're right until you confirm your guess, say by checking the woman's birth certificate.

The closest thing we astronomers have to a birth certificate for a galactic merger is its electromagnetic spectrum. As I noted earlier, when galaxies collide, the stars don't hit one another. But the puffy clouds



G515, a galaxy 1.2 billion light-years from Earth, was formed by a pair of galaxies that have nearly finished merging. The shadowy wisp in the lower half of this negative image, taken in infrared light, is made up of stars that still haven't settled into the main mass.

of cold gas in those galaxies do; and when their orbits are disrupted, the gas clouds can spiral inward toward the center of gravity of the merging system, where they are consumed in a tremendous, short-lived burst of star formation. When that happens, we can measure the spectrum of the stars formed in the burst and compare it with the spectra of other stars of known ages. By that method, we've confirmed that the flurry of star formation in G515 took place almost exactly a billion years ago.

Here's where the new mystery arises. My colleagues and I had to make sure that no substantial star formation continues today in G515, because that would throw off our esti-

mates for the age of the post-collision starburst. We looked through the archival database of the National Radio Astronomy Observatory for excess radio-energy emissions from the galaxy. Such energy could be emitted by hot, young stars that might have been born more recently than a billion years ago. What we found instead was a surprise: In 1995 the Very Large Array (VLA) telescope in New Mexico had detected substantial radio emission from G515. But measurements made by the same telescope in 2000 showed none!

Two possible explanations come to mind. The two VLA measurements were made with two different instrumental setups, so in 2000 the radio emission might simply have been missed. Our statistical analysis of the data, however, shows that possibility is remote. The other possibility is that we have detected a supermassive black hole. Radio emissions from such objects can vary widely, or even shut down and restart, in periods as short as a few years or even a few months.

Supermassive black holes have been detected at the centers of just about every large elliptical galaxy ever examined, and large elliptical galaxies are almost always created by mergers. Understanding what such a black hole is like just as an elliptical galaxy matures could reveal unexpected insights into the process of galaxy transformation. With that in mind, this past June my colleagues and I trained the VLA once again on G515. The new, more detailed data, which we are still analyzing, will help us determine whether the radio emission is back—and, if it is, whether or not it's coming from the center of the system, where any supermassive black hole should be lurking. If we find something, we'll definitely let you know.

CHARLES LIU is a professor of astrophysics at the City University of New York and an associate with the American Museum of Natural History.

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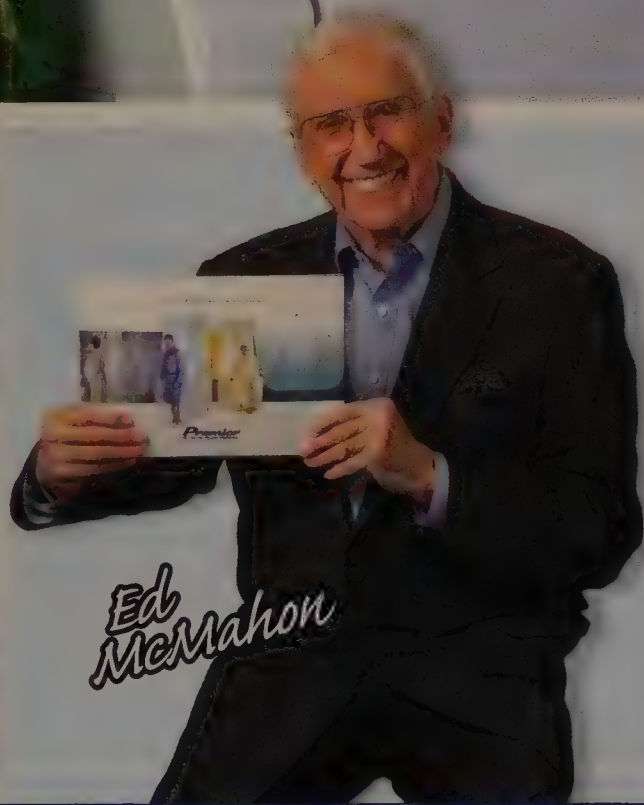
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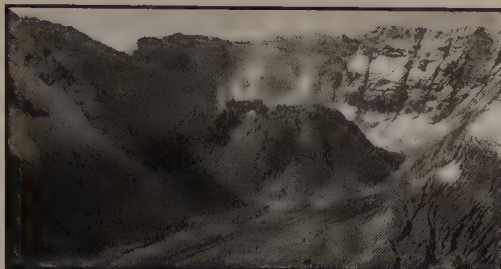
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On May 18, 1980, Mt. St. Helens exploded in the most deadly volcanic eruption in the history of the United States.

Image courtesy of USGS/Cascades Volcano Observatory.

Like many geologists, Dr. Renton is plainspoken, no-nonsense, rugged, and with a tinge of romanticism. He is also an award-winning educator with 40 years of experience teaching introductory geology at West Virginia University. You will find him spontaneous, well-organized, funny, and easy to follow.

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At the Museum

AMERICAN MUSEUM OF NATURAL HISTORY 

www.amnh.org

Young Naturalist Awards 2007

A research-based essay contest to promote participation and communication in science

Every year scientists from the American Museum of Natural History travel far and wide on expeditions to learn more about the natural world. The Young Naturalist Awards, now in its tenth year, invites students in grades 7–12 throughout the United States and Canada to follow in those footsteps, embarking on their own expeditions in the areas of biology, Earth science, or astronomy. Their research can be conducted as close to home as their backyard or a local pond or stream.

After identifying a question, students plan how they will gather information, conduct outside research to learn more about their topic and possible methodologies, observe their subjects, and record their findings. Finally, their data analysis results in conclusions that either answer the original questions or lead to further inquiry.

Included here are descriptions of and excerpts from the winning essays. Full-length versions of the winning essays and information on how to enter the contest are published on the Museum's Web site at www.amnh.org/youngnaturalistawards.

The Young Naturalist Awards program is sponsored by the Alcoa Foundation.



The 2007 Young Naturalist Awards winners

Algae in the Wekiva River: Is It Helping or Hurting Water Quality? by Ashley Hunt (Grade 7)

When a local newspaper reported that algae was threatening the Wekiva River, Ashley collected algae samples and conducted a macroinvertebrate survey at three sites along the river. She discovered that the healthiest sites had the least amount of algae.

"My family has a boat docked there so we can enjoy the peaceful river anytime we want to. Never once had the thought crossed my mind that the river might possibly be polluted."

The Toads of Delaware County, by Noah McDonald (Grade 7)

After finding a nearly eight-centimeter-long toad in his backyard, Noah wondered what type of habitat toads

preferred. He did a site survey, chose four different park preserves in which to carry out toad surveys, and, after analyzing his data, determined which park provided the best toad habitat.

"One summer afternoon I found this gigantic toad in the grass. I had lots of questions about this huge toad. I wanted to know all about its life cycle, and where and how it lives."

An Analysis of Water Quality on the Severn River over Two Years, by Alexandra Day (Grade 8)

Concerned that sediment runoff into the Severn River would find its way to the Chesapeake Bay, Alexandra decided to investigate the connection between rainfall and the amount of sediment in the Severn. In a two-year study, she collected water samples from two sites; inconclusive results led Alexandra to consider other factors, such as nearby construction and development.

"On the surface, a little rain may seem like a harmless thing. Where I live, on the Severn River, a tributary of the Chesapeake Bay, rain can cause excess erosion, which presents a major problem to the bay's health."

Lighter, Brighter, and Cooler: An Analysis of the Effect of Roofing Albedo on Ambient Temperatures, by Ryan Wham (Grade 8)

Ryan investigated whether high-albedo, or reflective, roofing material would lessen surrounding air temperature. He built four doghouses, some with high-albedo roofing and others with standard roofing, and measured surface and interior temperatures over several months. His data indicated that high-albedo roofing results in lower surrounding temperatures.

"It is becoming increasingly obvious that our climate is warming. I decided to do some research to try to better understand what is happening to our Earth."

Investigation of Water Quality in Mercer County Lake, by Alex Nagler (Grade 9)

When a local park ranger chased Alex and his dog out of Mercer County Lake, Alex became curious about the safety of the lake water. He tested the lake's water at four different sites over five weeks, and concluded that the data did not support his hypothesis that the water was safe, and that additional

data was needed before he could confirm that the lake was healthy.

"Given the natural beauty of Mercer Lake and its surroundings, it's easy to forget that it is situated within a densely populated part of the state. Heavily trafficked roads surround it, and two golf courses adjoin its shores. . . . I decided I would do my own investigation and find out more about the water in Mercer Lake."

Barn Owls on the Side of the Road, by Jon Atkinson (Grade 9)

Finding dead barn owls along a stretch of highway compelled Jon to search for the cause. He did research on barn owls and collected and dissected owl pellets. He hypothesized that owls flying low over the highway were hit by trailer trucks [see illustration below]. Jon plans to continue gathering data he hopes will provide a more conclusive answer.

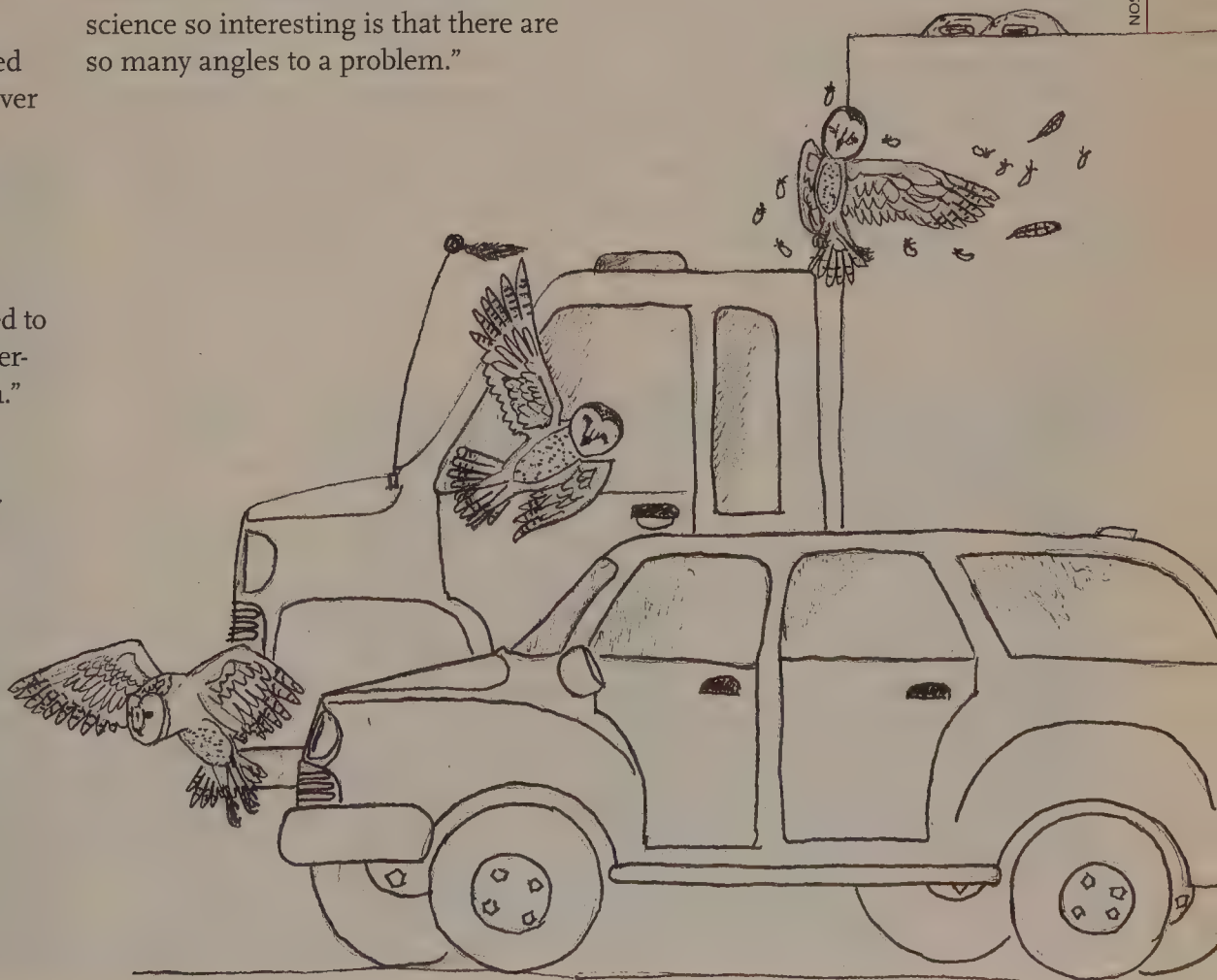
"In science everything is related. Solutions to problems might be in places that we do not expect, like studying mice in order to save owls. What makes science so interesting is that there are so many angles to a problem."

From the Desert to the Subalpine Forest, by Viola Li (Grade 10)

On a family vacation to the Grand Canyon, Viola hypothesized that the higher the elevation, the greater amount of flora would be present, but that at 7,000 feet, that diversity would begin to decline due to the harsher climate. Her data, collected from sites spanning 1,749 to 10,371 feet in elevation, supported her hypothesis.

"Every day, hundreds of people experience a phenomenon while gazing down into the almost 9,000 foot drop of the Grand Canyon. Yet, for me, as my eyes scanned the cliffs, this phenomenon was not only the expected hues and shadows of the cliffs that varied with every passing second, but also the diverse vegetation growing in there."

Thigmomorphogenesis in *Pisum* Tendril Development, by Nikola Champlin (Grade 10)



COURTESY JON ATKINSON



COURTESY NOAH McDONALD

Nikola studied a pea plant's ability to alter its growth form in response to an environmental condition such as wind. She discovered that the pea plant, a climbing species, has "searcher" tendrils, which search for support and "support" tendrils, which cling tightly to a support. Nikola found that, when subjected to an oscillating fan, pea plants produce a greater ratio of searcher tendrils.

"Phenotypic plasticity and thigmomorphogenesis are new areas of focus in research and there are still many unanswered questions about these topics. Hopefully, finding the answers will lead to a more knowledgeable breeding and selecting of plants and a greater understanding of how the environment impacts the development of plants."

Human Factor IV: The Impact of a Boiling Water Nuclear Reactor on the Plankton, Benthic, and Biofouling Communities in the Reactor's Intake and Discharge Creek, by Anastasia Roda (Grade 11)

Over the last four years, Anastasia has explored the impact that a boiling water nuclear reactor has had on its intake and discharge creeks. After studying microbial communities and water quality in the creeks, Anastasia compared her findings to those of a control creek. She concluded that the Oyster Creek Nuclear Generating Station has reduced the number and diversity of plankton, benthic, and bio-

fouling communities in the discharge creek.

"My four brothers and I spend summers along Barnegat Bay. We learned to kayak to the sedge islands in the bay and explore the islands' riches. Along the shore of the bay we watched more extraordinary sunsets than I can count, as the days ended and the mysteries of night enveloped the estuary."

A Survey of the Birds of Indroda Nature Park in Gujarat, India, by Arjun Potter (Grade 11)

During a summer vacation to India, Arjun decided to use his bird identification skills to conduct a field survey of the avifauna in Indroda Nature Park. Each day Arjun and his guide, the park warden's son, went to different habitats within the park; in all, they counted 1,451 birds representing 78 species.

"The Asian koel calls incessantly from the folds of the neem tree outside, and I open my eyes. A house sparrow dodges the whirring fan blades and lands daintily on top of the ceiling fixture. Oblivious of my gaze, she tucks another blade of dry grass in the nest above the fan. A house sparrow worthy of its name, I think."

More Than Meets the Eye: Do *Himasthla* sp. B Cercariae Use Chemo-orientation, by Joanna Nishimura (Grade 12)

Joanna wondered how parasitic flatworms were able to find their specific hosts in each part of their life cycle—through trial and error? Or did they, as Joanna suspected, respond to chemicals released by their hosts? Data she collected on the behavioral changes in the parasite when in the presence of its host supported her hypothesis.

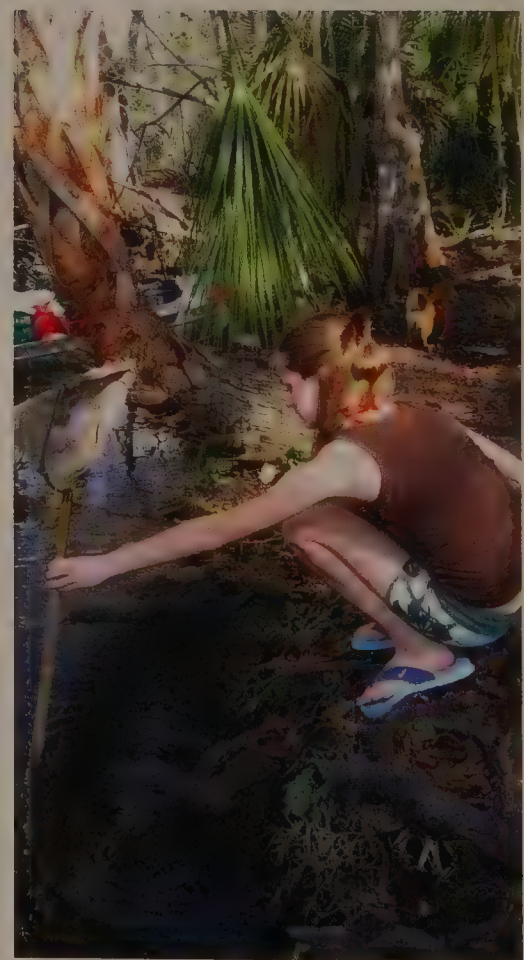
"I start out prostrate on the mud, my nose mere inches away from the

ground. Gradually my knees sink almost a foot beneath the surface, making odd squelching noises each time I attempt to move. Equipped with small mesh bags, I search for the most elusive organism of the Carpinteria Salt Marsh, the tiny, four-millimeter-long sea slug, *Acteocina*."

Lichens as Indicators of Vehicle Pollution, by Jeremy Koelmel (Grade 12)

Jeremy questioned whether certain lichen species could be used as indicators of traffic-related air contamination in a large urban area such as New York City. He chose low-, medium-, and heavy-traffic sites, surveyed the lichens found in each zone, and concluded that *Punctelia rudecta* (speckled shield lichen) is a good indicator of vehicle-based pollution.

"As vehicle exhaust increases or decreases depending on our future choices, we will be able to determine its quantity in certain areas through indicative lichen species such as the ones that may be determined in this experiment."



COURTESY ASHLEY HUNT

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY 

EXHIBITIONS

Mythic Creatures: Dragons, Unicorns, and Mermaids

Through January 6, 2008

Mythic Creatures traces the origins of legendary beings of land, sea, and air. Cultural artifacts bring to light surprising similarities—and differences—in the ways peoples around the world have depicted these beings, and fossil specimens suggest a physical basis for the many forms they have taken.

Mythic Creatures: Dragons, Unicorns, and Mermaids is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with The Field Museum, Chicago; Canadian Museum of Civilization, Gatineau; Australian National Maritime Museum, Sydney; and Fernbank Museum of Natural History, Atlanta.

Mythic Creatures is proudly supported by MetLife Foundation.

Undersea Oasis: Coral Reef Communities

Through January 13, 2008

Brilliant color photographs capture the dazzling invertebrate life that flourishes on coral reefs.

Beyond

Through April 6, 2008

Exquisite images of our planetary neighbors from unmanned space probes.

The presentation of both *Undersea Oasis* and *Beyond* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply.

All programs are subject to change.

AMNH eNotes: a monthly email on Museum programs and events. Sign up at www.amnh.org today!



COURTESY OF WANGARI MAATHAI

LECTURE

An Evening with Wangari Maathai

Tuesday, 9/25, 7:00 p.m.

Nobel Peace Prize laureate Wangari Maathai, celebrated political activist, feminist, and environmentalist, will share the story of her life as told in her autobiography, *Unbowed*.

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A live presenter leads this family-friendly visit to the Moon.

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Predawn Planets

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HAYDEN PLANETARIUM SHOWS

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Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum. Made possible through the generous support of CIT.

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life these intriguing animals.

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Friday, 9/14, 9:00 p.m.–1:00 a.m.

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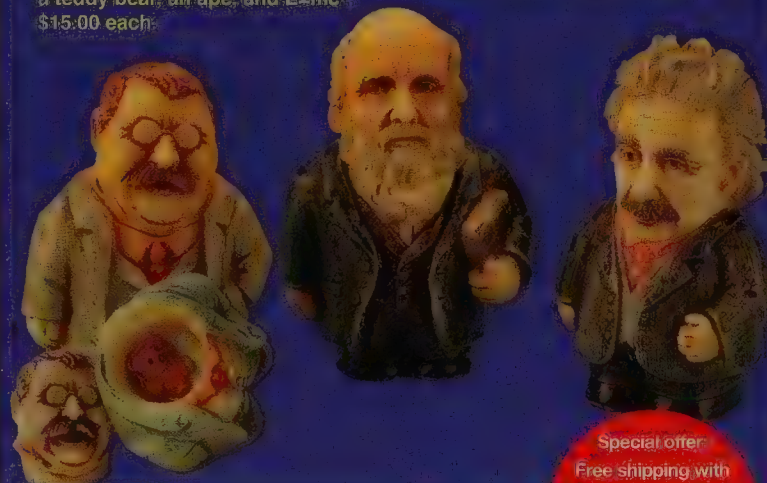
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THE SKY IN SEPTEMBER

By Joe Rao

Mercury remains a poor evening apparition in the Northern Hemisphere all this month, despite the increase in its angular separation east of the Sun throughout most of September. That's because the planet sets unfavorably early, only about forty-five minutes after sunset. Nevertheless, Mercury is worth a look with binoculars on the evenings of the 21st and 22nd. That's when it makes a close approach to Spica, the brightest star in the constellation Virgo, the virgin. Look for the pair just a few degrees above the west-southwestern horizon about thirty minutes after sunset.

Venus erupts into view in the eastern morning sky as September opens, rising just after dawn's first glow at around 5:00 A.M. local daylight time. With each passing day, this morning "star" rises higher and becomes a little brighter. By month's end, it is rising at around 3:30 A.M., some three and a half hours before sunrise. Venus was at inferior conjunction on August 18, in line between the Earth and the Sun. Now it is swinging away from that line, speeding ahead of Earth in its faster orbit. So through a telescope, the planet displays a large, brilliant crescent that wanes in phase all month while it shrinks in size.

Mars rises about four and a half hours after sunset and is high in the south-southeast by dawn. The planet begins the month in the constellation Taurus, the bull, seven and a half degrees to the lower left of the bright star Aldebaran—easy to mistake for Mars because of its similar hue. By month's end, Mars has shifted eastward to the feet of the constellation Gemini, the twins. We are slowly catching up to Mars in our orbit around the Sun. As a result, the Red Planet brightens by almost 50 percent this month, from magnitude +0.3 to -0.1, and, viewed in a telescope, its apparent size is slowly growing.

Jupiter, shining steadily in the southwest, five or six degrees above the ruddy but much dimmer star Antares, is the

first "star" to appear in the darkening sky. That makes an ideal test for the old adage that stars twinkle, whereas planets (usually) don't.

Saturn rises as morning twilight begins on the 12th, just after 5:00 A.M. local daylight time, and is one and a half degrees to the lower left of the bluish star Regulus. By the end of the month, a telescope of at least thirty power shows the ring system tilted 8.8 degrees from edge-on, with the south face visible—the closest to edgewise the rings have appeared since 1995.

The **Moon** is at last quarter on the 3rd at 10:32 P.M. and further wanes to new on the 11th at 8:44 A.M. Our satellite waxes to first quarter on the 19th at 12:48 P.M. and to full on the 26th at 3:45 P.M. That full Moon is called the Harvest Moon, because it is the one nearest in the calendar to the autumnal equinox.

On the morning of the 1st the **Alpha Aurigid meteors** seem to dart from the bright star Capella, in the constellation Auriga, the charioteer. Normally the Alpha Aurigid shower is too minor to be worth mentioning, but Peter Jenniskens, an astronomer at the SETI Institute in Mountain View, California, is forecasting a dramatic outburst of as many as hundreds of meteors an hour. If the display does come to pass, however, it will only be visible from the western United States and Canada. The peak is due at 4:37 A.M. PDT, when the rest of North America is already in daylight.

The **equinox** takes place on the 23rd at 5:31 A.M. Autumn begins in the Northern Hemisphere; spring in the southern.

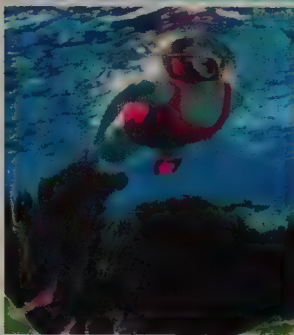
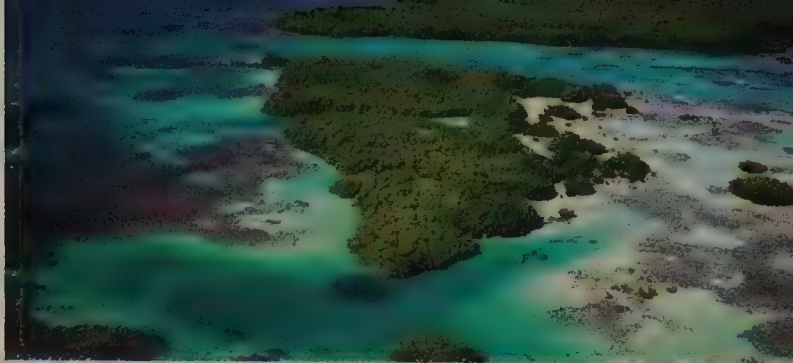
A **partial eclipse of the Sun** takes place on the 11th, but it is visible only from about half of Antarctica and the southern two-thirds of South America.

Unless otherwise noted, all times are eastern daylight time.

Belize Barrier Reef

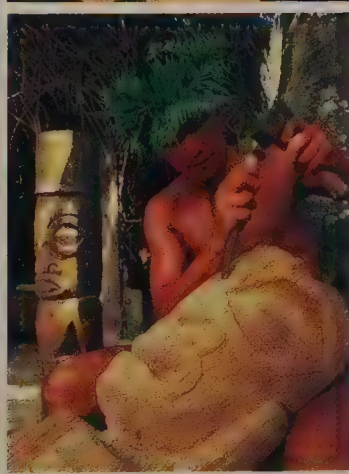
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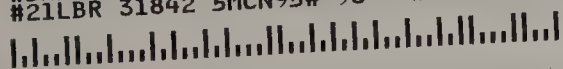

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LUCY'S JOURNEY

Belize Recollections.

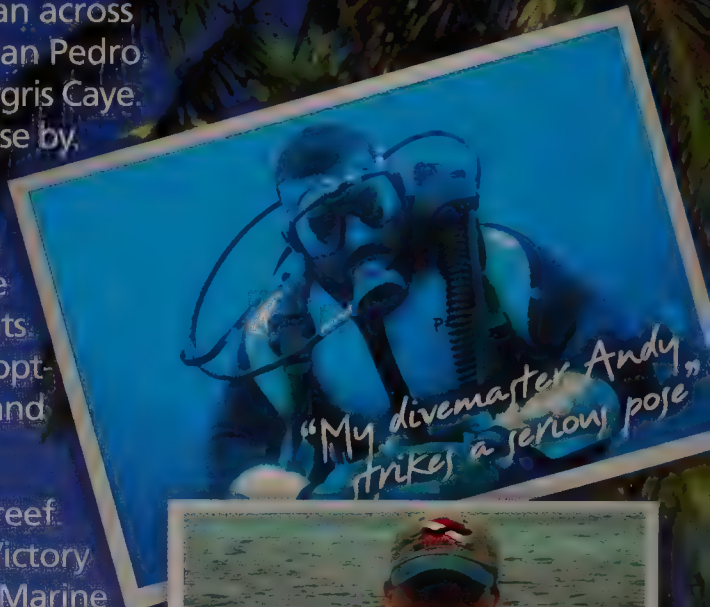
"I was flipping through Scuba Diving magazine. Ran across an article on Belize. "Got to go," I said. Stayed in San Pedro. The town sits on the limestone coral island of Ambergris Caye. Turquoise waters. Pristine beaches. Maya temples close by. You fall in love quickly.

Was prepared for tidal wave of tourists aka Cancun or Cabo. I was surprised. Plenty of people. Just more laid back. Folks drift in and out of bars and restaurants. The smell of garlic and seafood lingers in salty air. I adopted the local beer and seafood diet. Easy to understand once you're here.

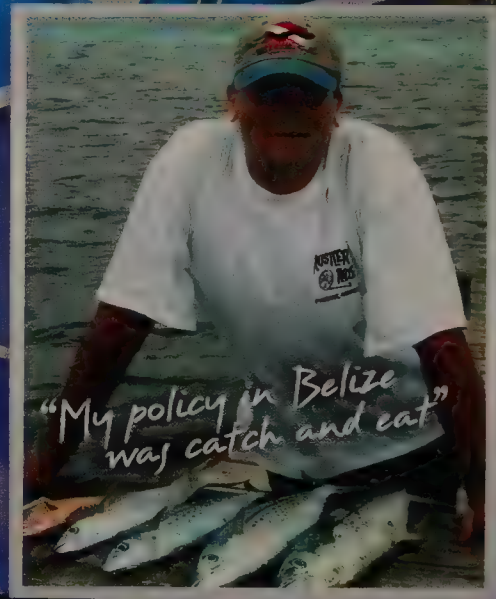
The town is snorkeling distance to Belize's barrier reef. Also got in some great diving. M and M Caverns. Victory Tunnel. Hol Chan Marine Reserve. Reef is stunning. Marine life spectacular. Liked it so much just kept going back. My divemaster, Andy Palacio, now a friend. No strangers here. People of Belize lead with their hearts. Nice change from many places I've been.

One very, very special place. I'm homesick just thinking about it."

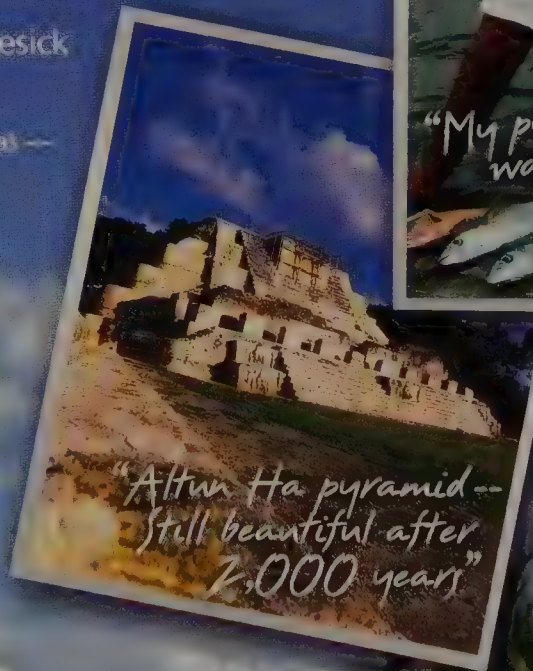
—Tibor Karakas—



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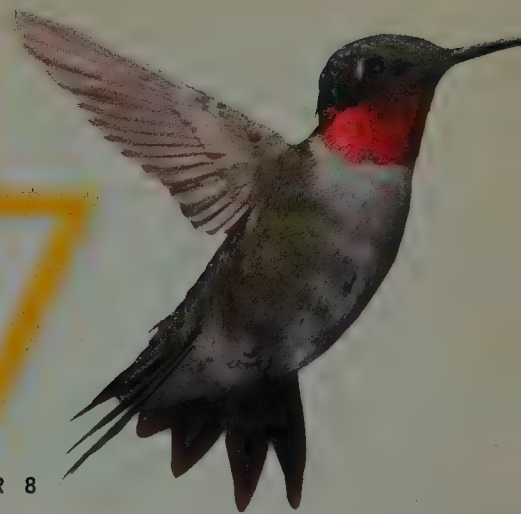
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NATURAL HISTORY

OCTOBER 2007

VOLUME 116

NUMBER 8



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The fishes of the deep sea are particularly vulnerable to overfishing.

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African spiders get the jump on blood-filled mosquitoes.

SIMON D. POLLARD
AND ROBERT R. JACKSON

ON THE COVER: Reconstruction of *Australopithecus garhi*, a close relative of *A. afarensis* (Lucy), based on a 2.5-million-year-old Ethiopian fossil. The image is a detail from a digital mural by Viktor Deak, commissioned for "Lucy's Legacy: The Hidden Treasures of Ethiopia," an exhibition now running at the Houston Museum of Natural Science through April 20, 2008.

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THE NATURAL MOMENT

Phantom of the -Opteras

Photograph by Christian Ziegler

◀ See preceding two pages



Walking sticks are creeping up on the 250th anniversary of their scientific debut: The Swedish taxonomist Carl Linnaeus first chronicled three species in 1758, calling them the phasmas, or ghosts, of the insect world. The moniker stuck, though it morphed to “phasmids,” and it speaks aptly of the creatures’ knack for appearing and disappearing among the twigs they mimic. Since Linnaeus, more than 2,800 species of the spindly apparitions have been sifted like needles from arboreal haystacks, and identified.

The egg capsules of the insects have been crucial to their classification. Females, which often become pregnant without males by way of parthenogenesis, deposit eggs on a weekly, if not daily, basis—depending on the species. Some eggs are glued to leaves, others buried or simply dropped on the soil; some hatch in a month, others take a year or more; some are the size of pinheads, others of pine-nut proportion. Certain eggs look so much like seeds that they get protection from ants that tote them back to their nests.

Photographer Christian Ziegler gathered the egg capsules pictured here on a moist forest floor in Panama. The newborn he caught emerging from one of the egg capsules slid out fluidly, long legs last. After five or six molts the nymph will grow to full maturity. Each molt will also give it a chance to regenerate any lost limbs—and refine the art of self-masking.

—Erin Espelie

Shallow-Water Thinking

Go and look in the fish markets,” Richard L. Haedrich tells me, “and you’ll see all kinds of fish spread out there. But you won’t know where any of it really comes from. They give you the country of origin, but they don’t tell you that the Chilean sea bass you’re about to buy is a deep-sea fish that lives for a very long time. It’s quite tasty, I’ve been told, but I would never eat Chilean sea bass—and I would probably never eat orange roughy for the same reason.”

Haedrich, a biological oceanographer and ichthyologist who is an emeritus professor at Memorial University in St. John’s, Newfoundland, has devoted most of his professional life to studying deep-ocean ecosystems. The problem with taking fish to market from the deep sea, as he notes in his article, “Deep Trouble” (page 28), is the slow pace of life there. No sunlight can penetrate to the waters along the continental slopes, at least a hundred fathoms below the surface, where deep-sea trawlers drag their fifteen-ton rigs. Fishes that survive in that gloom rely on a rain of organic matter from the surface layers of ocean. They adapt, Haedrich explains, by “slowing down, living longer, maybe taking longer to mature.”

In consequence, he points out, “turnover times for any sustainable fishery in the deep sea are much longer” than they are for the shallow-water fishes that have been the customary targets of the world’s commercial fishermen. “That is a fact well-known to deep-sea biologists and deep-sea oceanographers, but it seems that shallow-water thinking has been used” to gauge what can be taken from the deep sea. The result is that “a lot of deep-sea fishing operations have been more like mining operations,” Haedrich says. “You clear out one area, go to another area, clear it out, and so keep moving on.”

What is to be done? “I think one of the things that consumers ought to do is ask fishmongers where their fish come from, and whether they are taken in a sustainable way,” Haedrich suggests. “Only then can the kind of lifestyle practiced by fishermen, and the kind of valuable food they provide, continue for generations to come.” To hear the full audio recording of my interview with Richard Haedrich, go to our Web site (www.naturalhistorymag.com); you’ll find the audio link on our home page.

• • •

The image on our cover this month was made by Victor Deak, one of the most accomplished paleoartists of our generation. Deak’s work last appeared on the cover of *Natural History* in February 2007; this month’s cover is a detail from a mural commissioned by the Houston Museum of Natural Science for a special exhibition on Ethiopian archaeology, art, and history, running now through April 20, 2008. The centerpiece of the exhibition is a 3.18-million-year-old fossilized skeleton of a female member of the species *Australopithecus afarensis*, which its discoverers named Lucy. In “Lucy Goes Walkabout” (page 26), Ian Tattersall, a curator in the division of anthropology at the American Museum of Natural History in New York City, describes Lucy, her significance to the understanding of early humans, and what is so intriguing about her current travels abroad to Houston.

—PETER BROWN



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A tropical ecologist by training, **CHRISTIAN ZIEGLER** ("The Natural Moment," page 2) specializes in nature and science photojournalism. He serves as an associate for communication with the Smithsonian Tropical Research Institute in Panama, where he made the images for the book *A Magic Web* (Oxford University Press, 2002). His depictions of forest ecology were also featured in a traveling exhibition produced by the Smithsonian Institution and in an exhibit produced by *GEO* magazine. His photographs have won several international prizes in the *BBC Wildlife* Photographer of the Year and European Wildlife Photographer of the Year competitions. In 2005 Ziegler helped found the International League of Conservation photographers. This year he is collecting images for a new book and museum project, which will take him to the Americas and Asia. See www.naturphoto.de for more information.

RICHARD L. HAEDRICH ("Deep Trouble," page 28) is a biological oceanographer and ichthyologist who specializes in the ways deep-sea fishes relate to their environment. In spite of having what he calls "a strong distaste for getting wet," Haedrich has been chief scientist on numerous research cruises, initially based out of Woods Hole, Massachusetts, and later out of the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. He is an emeritus professor at Memorial University in St. John's, Newfoundland, where he has taught fisheries biology and oceanic biogeography since 1979 and played a lead role in directing oceanic research. His most recent work has focused on changes in the fishery ecosystem of Newfoundland before, during, and after the cod collapse of 1992. He is coauthor, with Nigel Merrett, of *Deep-sea Demersal Fish and Fisheries* (Chapman & Hall, 1997); and from 1999 until 2004 he was co-chair of the ocean fish subdivision of Canada's Endangered Species Committee. He lives in downtown St. John's with his wife, Susan; when not at sea, he enjoys cycling and playing trombone in the easternmost jazz band in North America.



Pollard



Jackson

Based in Christchurch, New Zealand, coauthors **SIMON D. POLLARD** and **ROBERT R. JACKSON** ("Vampire Slayers of Lake Victoria," page 34) are spider biologists who have worked together for almost thirty years. They met at the University of Canterbury, when Jackson was a junior member of the faculty and Pollard was still an undergraduate. Now a full professor, Jackson has spent his career working with jumping spiders in order to understand the evolution of complex behavior in animals with tiny nervous systems. Pollard is now the curator of invertebrate zoology at the Canterbury Museum, as well as adjunct associate professor at the university. In addition to working with Jackson in Kenya, Pollard has been investigating the life of a species of crab spider that lives in the liquid reservoirs of pitcher plants in Asia.

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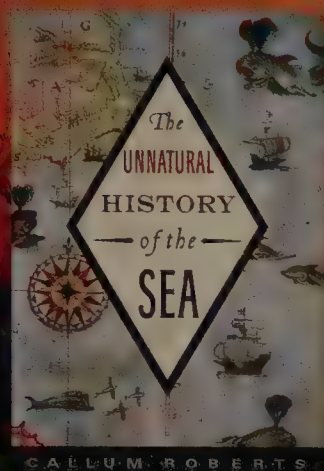
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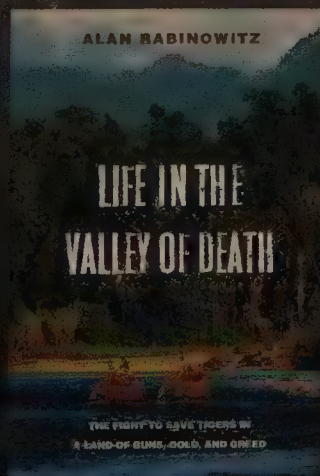
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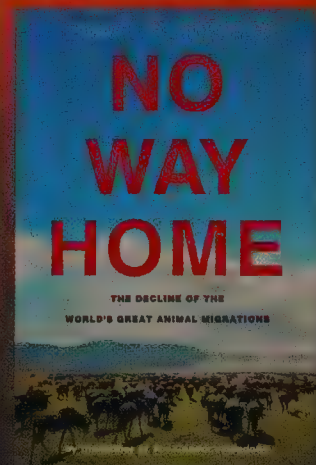
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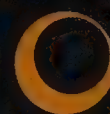
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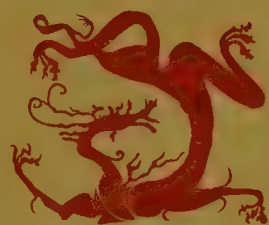
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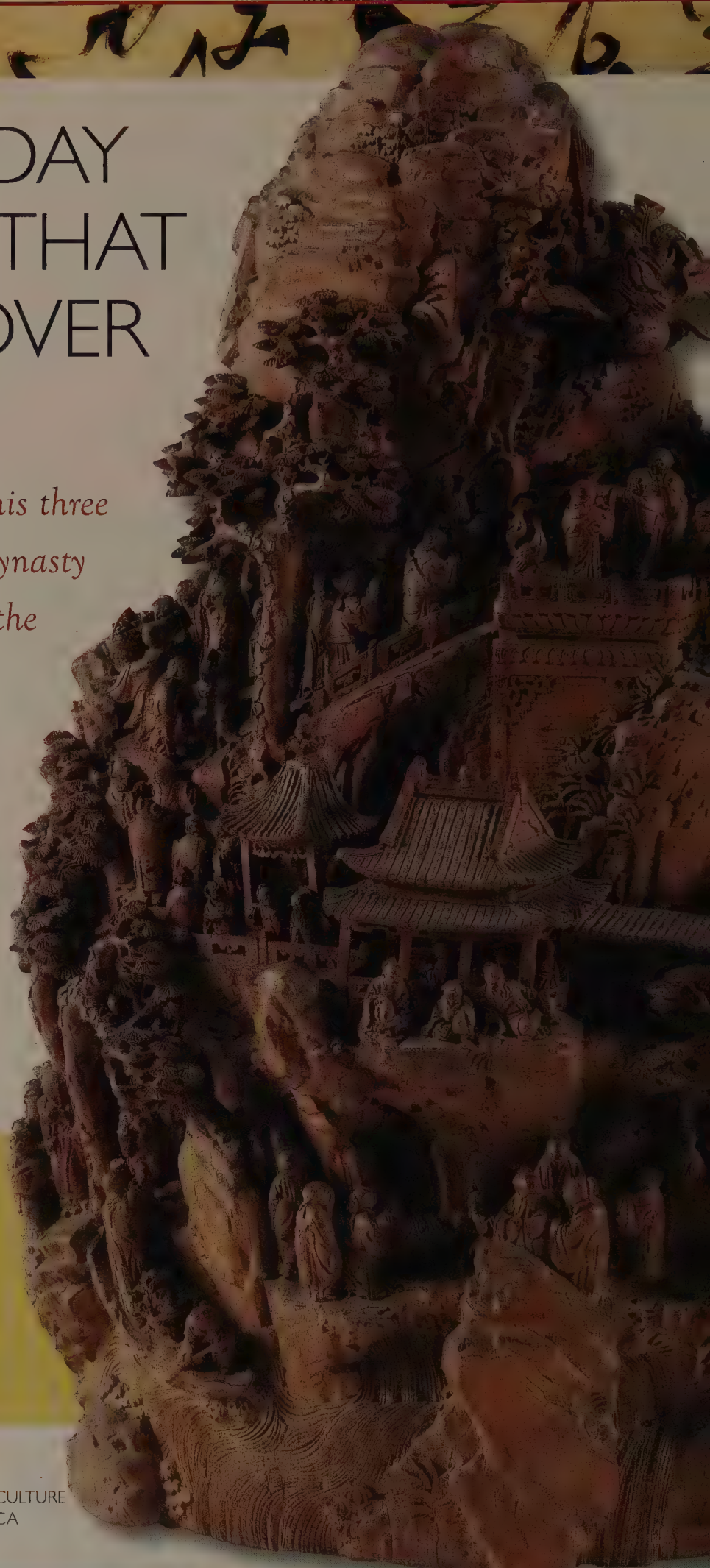


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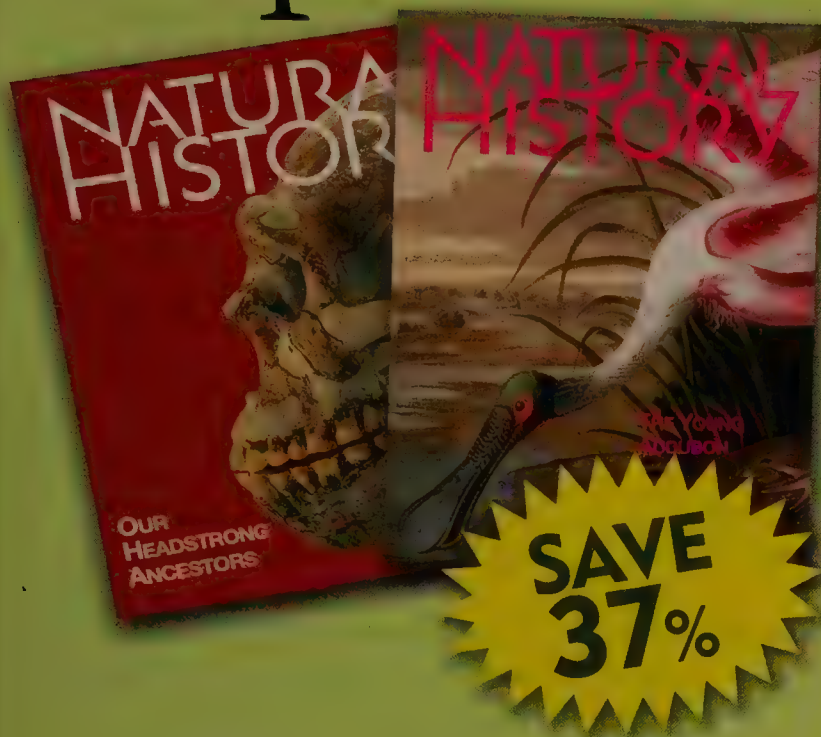
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LETTERS

Cut-rate Proteins

Olivia Judson's excellent article on the cell's use of relatively "cheap" amino acids ["A Terrible Scrooge," 5/07] made me wonder whether the principle could also apply to the so-called essential amino acids—the ones that people cannot synthesize and therefore have to consume. I always thought of our limited ability to synthesize as a shortcoming of our physiology. Now I wonder whether it is also part of the economic scheme: might it be cheaper to go to the grocery store for those molecules than to synthesize them?

Gabor Markus

Buffalo, New York

OLIVIA JUDSON REPLIES: Diet surely shapes the amino-acid composition of proteins—organisms that find it hard to obtain nitrogen, for instance, are less likely to use nitrogen-rich amino acids. But no one has determined whether the effect Mr. Markus suggests is operating. Intriguingly, however, the "essential" amino acids are abundantly available—not only in hunter-gatherer diets, but also in all human diets except the ones of specialized vegetarians.

Save the Vaquita!

I cried when I read "How Now, Little Cow" [7–8/07], Robert L. Pit-

man and Lorenzo Rojas-Bracho's article about the vaquita. I know people need to make a living, but it's not fair to do it at the expense of another species. The price tag the authors mention, \$25 million to eliminate the threat of bycatch, is a drop in the bucket to many entities and individuals.

Ken Cobleigh

Renton, Washington

Name That Plant

The plant identified as *Gloxinia macrophylla* on page 26 of Wm. Wayt Thomas's article, "Survival of the Rarest" [6/07] should be called *Sinningia macrophylla*. The current name can be found in the *World Checklist*

of *Gesneriaceae*. The plant is cultivated by members of the Gesneriad society.

Dee Stewart

Stow, Massachusetts

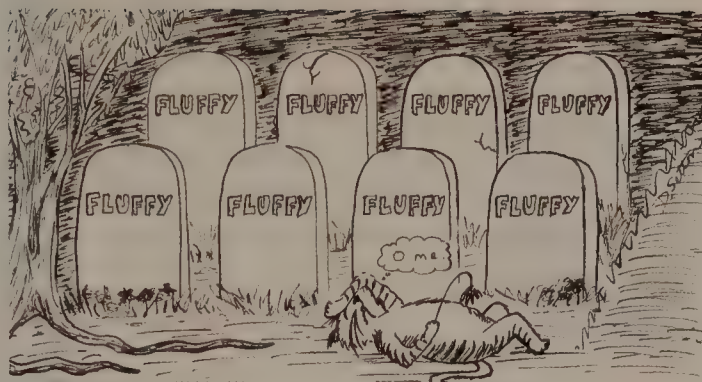
WM. WAYT THOMAS REPLIES: I knew that the plant belonged to the genus *Sinningia*, but the name *Sinningia macrophylla* is not listed in the standard reference, the *International Plant Names Index*. I believed that no one had made that nomenclatural combination. For simplicity, then, I said that the plant was originally described as *Gloxinia macrophylla*.

Ask the Experts

I hope you can answer a question I have had for



many years. One October years ago (maybe between 1943 and 1945), in northwestern Wyoming at about 7,500 feet elevation, we were bringing horses home from a cattle drive when, between 8 and 10:30 p.m., we were blessed with a meteoric shower of exceptional quality. In these few hours I saw roughly half the "stars" I have seen in all my life. Quite a number of them whistled, hissed, and so on when (I assume) they hit the atmosphere. We had quite an argument about that because I had read that meteors would be about thirty miles above us, but we heard them instantly—as if they



Fluffy broods over his reckless ways.

were a quarter mile away. How is that possible?

Jack Lozier

Quesnel, British Columbia

JOE RAO REPLIES: From Jack Lozier's description, the meteor display was the Giacobinid meteor storm, which took place on the evening of October 9, 1946. Comet Giacobini-Zinner had

crossed Earth's orbit fifteen days earlier, and bits of dusty debris from its wake pelted our atmosphere at roughly twenty miles a second, creating the "shooting stars." The astronomer Colin Keay suggests that the simultaneous meteor sounds Mr. Lozier describes arise by electrophonic transduction: the wake of the

meteor traps its own magnetic field, generating long radio waves. When the radio waves interact with ground-level objects such as trees, they create audio waves: sound. The same principle may explain reports of auroral sounds, the unease of animals before earthquakes, and sounds heard before lightning strikes nearby.

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Crabs (*Shinkaia crosnieri*) crowd a deep-sea hydrothermal vent, where bacteria related to human pathogens were recently discovered.

They Came from the Deep

What does a deep-sea thermal vent have in common with the inside of your gut—apart from a tendency to rumble and grumble? It turns out the two places are home to bacteria with a surprising evolutionary connection.

A team led by Satoshi Nakagawa of the Japan Agency for Marine-Earth Science and Technology isolated two previously unknown bacterial species from vents near Japan. The team then compared the new species' genomes to the genomes of two common gut pathogens, *Helicobacter*, which causes ulcers, and *Campylobacter*, which causes diarrhea. The comparison showed that despite eons of evolutionary divergence, the deep-sea species and the pathogens share genes that enable them to colonize animal hosts.

The products of the genes in question enable bacteria to evade host immune systems and stick to host tissues. The pathogens put the genes to work when they infect people or other animals. But the deep-sea bacteria aren't pathogenic. Instead they probably live on the surfaces of shrimp and worms and in snails' gills, and make their living converting chemicals from the vents into energy; their animal hosts house them in return for food. Nakagawa thinks the shared genes evolved in the deep sea to enable symbiosis with animals. Eventually, toxin-secreting pathogens evolved from deep-sea bacteria and repurposed the genes for the more nefarious goal of mounting infections. (PNAS)

—Rebecca Kessler



Wood ant clutches conifer resin, a natural disinfectant.

Collective Medicine

Wood ants are industrious food gatherers, but why do they bother lugging home inedible gobs of solid conifer resin? The answer, according to a new study, is that the resin disinfects the nest and helps keep the ants free from disease.

Michel Chapuisat and Philippe Christe of the University of Lausanne in Switzerland and two colleagues collected adults and larvae of the wood ant *Formica paralugubris* in the Swiss Jura Mountains. The team placed the ants in experimental containers and exposed them to a bacterium and a fungus that killed most of them within a few weeks. But small pieces of resin added to half the containers greatly improved survival rates for larvae exposed to both the fungus and the bacterium, and for adults exposed to the bacterium.

The resin seems to have antibiotic properties. The investigators think it might release volatile compounds that inhibit the growth of microorganisms in the nest. It's also possible that the ants coat themselves with antibiotics when they touch resin gobs. A few other animals, such as starlings, line their nests with fresh leaves thought to hinder blood-sucking mites and fleas. Chapuisat and Christe's ant study, however, is the first to prove that enlisting plant material to combat pathogens improves survival in a nonhuman animal. (Proceedings of the Royal Society B)

—Stéphan Reeb

Australia's Rip Van Winkle

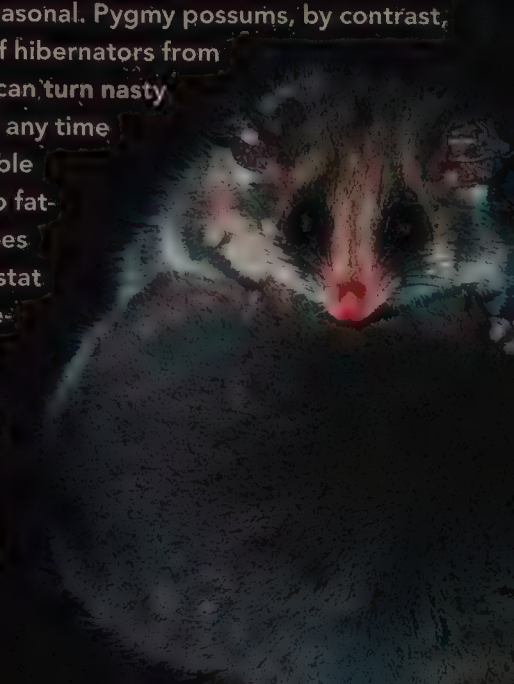
If hibernating were an Olympic sport, pygmy possums would be gold medalists. One of the mini-marsupials dozed for a record 367 days, according to Fritz Geiser of the University of New England in Australia. The key to soporific success lies in the pygmy possums' weight-gaining prowess: they can quickly balloon from 0.7 ounce to a supersize 1.9 ounces when food is plentiful. Those enormous fat reserves fuel the big sleep.

Geiser observed a small colony of captive pygmy possums after first letting them fatten up on high-energy food, then cutting off the feast and mimicking the winter light and temperature of their native habitat in southeastern Australia's forests and heaths. The chilly darkness and lack of food triggered hibernation: the animals spent increasingly lengthy periods in a state of torpor, punctuated by brief bouts of activity. The snoozing pygmy possums slashed their energy expenditure to less than 3 percent of that predicted for active animals.

Most hibernators live in northern climates where food and weather are predictably seasonal. Pygmy possums, by contrast, are among just a handful of hibernators from places where the weather can turn nasty or food stocks can crash at any time of year. In such unpredictable climes, it pays to be able to fatten quickly in the good times and turn down the thermostat as needed for extended periods to ride out the bad. (Naturwissenschaften)

—Nick Atkinson

Fur balls: two pygmy possums, one lean and active, on top, the other, fattened for hibernation



The Kindness of Strangers

"One good turn deserves another." Most people take that aphorism to heart—so much so, studies show, that after receiving help, we are more willing than before to help someone else, even a stranger. It might be tempting to think such virtue is unique to our species, but it turns out that the lowly rat is just as noble.

To find out if grateful rats would lend a paw to perfect strangers, Claudia Rutte of the University of Lausanne and Michael Taborsky of the University of Bern, both in Switzerland, trained rats to pull a lever that introduced food to a rat in a neighboring cage. On five consecutive days, trained test rats were caged either next to other helpful, trained rats or next to unhelpful, untrained rats. On the sixth day, Rutte and Taborsky

discovered, test rats that had been paired with helpful neighbors were, on average, 21 percent more likely to pull a lever for a new neighbor they had never encountered than were test rats paired with unhelpful neighbors.

What's more, the rats could distinguish between strangers and former benefactors. In another experiment, test rats that encountered a rat that had given them food earlier were—not 21 percent—but 51 percent more likely to return the favor. Notably, Rutte and Taborsky studied only female rats. No word on whether males would be equally obliging. (*PLoS Biology*)

—S.R.



Who's Your Mommy?

Animals aren't the only life-forms that can recognize their family members. Plants can too, it seems.

The sea rocket, *Cakile edentula*, is a member of the mustard family that grows on sandy beaches. Susan A. Dudley of McMaster University in Ontario and her student Amanda L. File measured the growth of sea rockets they had planted in groups of four. Sea rockets in groups of unrelated plants grew many fine roots, the better to compete with one another in the quest for water and nutrients. But when the plants in a pot were siblings that shared the same mother, they restricted their fine-root growth by about 13 percent. After all, there's no point devoting resources to competing with one's siblings when their reproductive success perpetuates one's own genes.

Dudley and File suspect that many plants can detect and recognize their kin. How plants do that remains a mystery, though cueing in to chemicals seeping from other plants' roots is one obvious possibility. Whatever the mechanism, Dudley and File have thrown open the door of plant research to altruism, cooperation, and other social evolutionary concepts once reserved for the study of animals. (*Biology Letters*)

—S.R.

That Sinking Feeling

New York City sinks 1,400 feet beneath the Atlantic; only the tip of the television tower atop the Empire State Building pokes above the waves. No, it's not a scene from the latest doomsday flick, it's what would happen if the rock underlying the city cooled to the temperature of the rock under northern Canada. And according to two geophysicists at the University of Utah, that's exactly what's in store. The only dry landmasses left from "our" North America will be the Rockies, the Sierra Nevada, and the Pacific Northwest. But don't worry: the cooling of Earth's mantle will take at least a billion years.

Derrick Hasterok and his graduate adviser, David S. Chapman, make their arresting prediction on the basis of a model they developed to illustrate how crust and mantle temperatures help determine the elevation of every place on Earth. Heat released by

the mantle makes the overlying crust more buoyant, raising it. But two other important factors—the composition and thickness of the crustal rock—have made it hard to quantify the role of heat alone. Hasterok and Chapman's model solves that problem for the first time by eliminating those factors mathematically.

Not every landmass will sink once the crust cools, they predict. Seattle, for instance, will no longer be a seaport, but a mile-high retreat. It is now insulated from mantle heat by a cold plate of rock that is slowly falling into the mantle. Once the plate completes its descent, the crust above it will warm—and rise—substantially. (*Journal of Geophysical Research—Solid Earth*)

—Harvey Leifert

Seattle, now a seaport, will be a mile-high city in a billion years or so.





A Hot New Trend

The European heat wave of August 2003 killed some 35,000 people; temperatures in many places topped ninety-five degrees for as long as ten days in a row. A new study shows that the lethal hot spell was part of a century-long trend toward higher summer temperatures and longer heat waves in Europe—and that earlier studies underestimated just how unusually severe recent heat waves have been.

Paul M. Della-Marta of the University of Bern in Switzerland and his colleagues analyzed weather data recorded for more than a century throughout Western Europe. The team discovered that the number of hot summer days—those among the warmest 5 percent ever recorded for their time of year—tripled from 1880 to the present. Meanwhile, the average length of heat waves doubled, to three days, and average summer temperatures rose by nearly three Fahrenheit degrees.

A hundred years ago, weather stations recorded higher temperatures than a modern installation would have, because they didn't properly shield their instruments from reflected light and heat. Della-Marta's team made the most accurate statistical correction of that bias to date, revealing that the change in length of today's heat waves had been underestimated by 30 percent. The trend toward longer, hotter heat waves will likely continue as the globe warms. (*Journal of Geophysical Research—Atmospheres*) —S.R.

Out of Sync

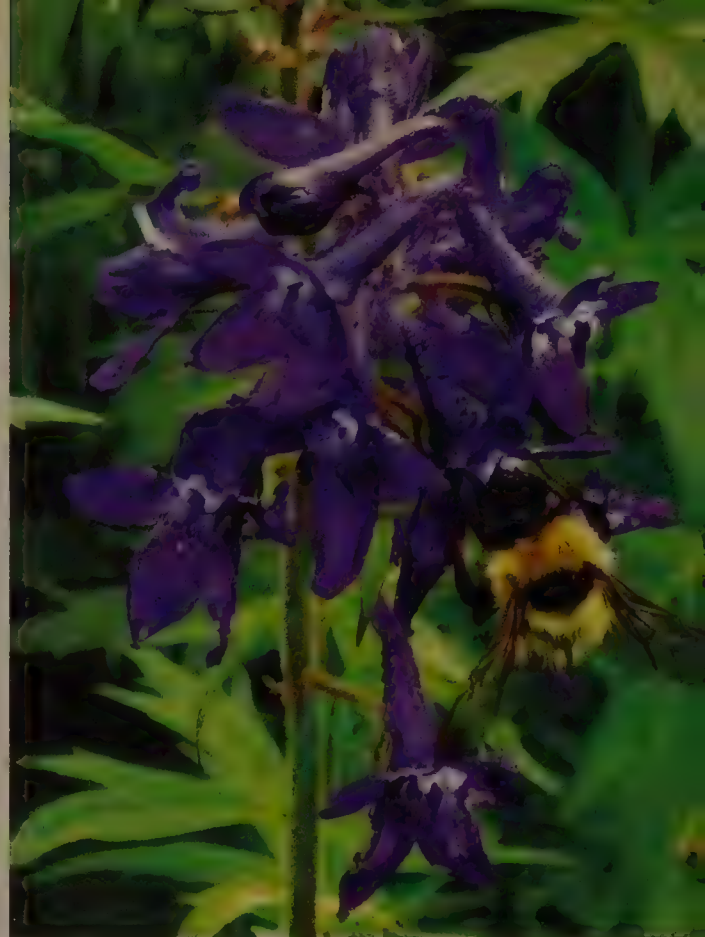
Flowering plants provide food to their animal visitors in exchange for pollination, so both groups are in big trouble if their schedules fail to mesh. Will global warming disrupt their timing and lead to a wave of extinctions? Until recently, a lack of data made it hard for biologists to estimate how large the potential effects might be.

So Jane Memmott of the University of Bristol in England and three colleagues dug into a 1929 tome, *Flowers and Insects*. The book had been largely inaccessible to modern ecologists until Memmott's team digitized it, page by page. Its author, Charles Robertson, catalogued nearly 15,000 associations between 429 plant species and their 1,420 pollinators, a trove of data he gathered in more than thirty years spent watching flowers in Illinois.

On the basis of timing shifts caused by global warming that have already been observed in several plants and pollinators, Memmott and her colleagues figured that by the end of this century the annual activities of plants and pollinators will advance by one to three weeks, depending on the species. The team then modeled how those forecasted

shifts would affect the extensive network described by Robertson. They estimate that between one sixth and one half of all pollinator species in northern temperate climates will face disruptions in their food supply lasting between a week and a month. And even a week is long enough for most insects to starve. Of course, the associations could evolve to become more resilient—but confirming that will require watching a lot more flowers. (*Ecology Letters*)

—Brendan Borrell



Bumblebee pollinates a larkspur flower.

Snow Gray

A billion people living in the dry regions of our planet owe their summer supply of freshwater to snowmelt from nearby mountains. To them, climate change will not be kind. In the future, alpine snow won't last as long as it does now—and not just because of rising temperatures. More frequent dust storms will sprinkle dirt onto the snow, darkening it and so increasing its absorption of the Sun's heat. The snow may melt so fast that water supplies could dry up by summer.

That's the warning sounded by Thomas H. Painter of the University of Utah and several colleagues. Working at a site in the San Juan Mountains of southwestern Colorado, the team

documented as many as eight dust storms each year from 2003 through 2006. The windborne dust came from deserts at least a hundred miles away, in Arizona and New Mexico. The team calculated that in 2005 and 2006, the darkened snow cover at their site disappeared between eighteen and thirty-five days earlier in the spring than it would have without a covering of dust.

Farming, grazing, mining, and recreation have long disturbed soil the world over, contributing to dust storms; more frequent and intense droughts projected for the southwestern United States and elsewhere as temperatures rise will only add to the problem. (*Geophysical Research Letters*) —S.R.

Dust storm whips
sand dunes in
Colorado.

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Called "the white dove of the desert," San Xavier del Bac is one of the finest examples of mission architecture in the United States

MISSION SAN XAVIER DEL BAC, IN THE SANTA CRUZ Valley nine miles south of Tucson, rises brilliantly white from the desert floor of dusty green mesquite and sage. A gem of Spanish colonial architecture—perhaps the finest example of mission architecture in the country—it was founded by the celebrated Jesuit missionary and explorer Father Eusebio Francisco Kino, who first visited Bac in 1692. In 1700, Father Kino laid the foundations of the first church and named it San Xavier; the present church was finished in 1797. With its imposing dome and lofty towers, rounded parapets and graceful spires, the mission is a graceful blend of Moorish, Byzantine and late Mexican Renaissance architecture. Inside, the church is made up of a series of domes and arches that create enclaves covered with colorful paintings.

Two archaeological parks preserve the state's Native American heritage. **Casa Malpais**, or "House of the Badlands," is surrounded by unusual beauty on a rim of volcanic rock overlooking the Little Colorado River's Round Valley. Perched at an elevation of 7,000 feet, the archaeological park offers breathtaking views of the White Mountains. Its pottery and architecture are similar to that of the ancient cultures of the

Traditional and contemporary art may look different,
but they all share the same spark of inspiration.



Seize the Day



Four Corners area. The Hopi and Zuni people claim an affinity to the site, and therefore some parts of it, considered sacred, are closed to tours. Casa Malpais may have been a ceremonial center used by people from surrounding pueblos as well as its own inhabitants for religious ceremonies. It may have also been used as a regional marketplace. It boasts a large great kiva—carved from volcanic rock—catacomb burials, three stairways, an intermittent wall that surrounds the site, an astronomical observatory, numerous solar petroglyph markers, and astronomically aligned shrines. The site was occupied for about 200 years, then abandoned some 600 years ago.

At **Besh-Ba-Gowah Archaeological Park** in Globe, you may walk through a 700-year-old Salado Culture pueblo, climb ladders to second-story rooms, and view the typical furnishings of the era. Considered one of the most significant finds of Southwest archaeology, Besh-Ba-Gowah has one of the largest single-site archaeological collections in the Southwest. It is one of the most complex of the Salado communities, and was once a ceremonial, redistribution, and food storage complex. Artifacts of this culture are also displayed in the Besh-Ba-Gowah Museum.



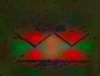
Anita Avalos

South of Globe, the 700-year-old Salado culture pueblo known as Besh-Ba-Gowah is one of the most important finds in Southwest archaeology

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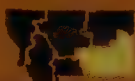
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Above left:
Makoshika State
Park at Glendive;
left: Tipis at
Little Bighorn
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as the leaves turn this fall →



DORCHESTER COUNTY

MUCH OF DORCHESTER COUNTY, in the heart of the Chesapeake Bay, has been declared a state heritage area because its unspoiled countryside preserves the traditions of life along the Chesapeake. Boasting 1,700 miles of shoreline, Dorchester is a haven for boaters and sailors and a great spot for crabbing and fishing. History buffs will enjoy a stroll through the tree-lined streets of downtown Cambridge, lined with rows of Federal and Queen Anne's houses. Dorchester was also the home of Annie Oakley, whose house was in Cambridge, and Harriet Tubman, memorialized in a garden in the town.

Twelve miles south of Cambridge, visit Blackwater National Refuge, whose 27,000-plus acres of woodland, tidal marsh, freshwater ponds, and managed cropland comprise one of the chief wintering areas for migrating ducks and Canada geese using the Atlantic Flyway. In addition to two species listed as threatened or endangered—the bald eagle and the Delmarva fox squirrel, which are seen regularly at the refuge—the refuge has a diverse population of birds including ospreys and great blue herons, mammals, reptiles, and amphibians. One of the best ways to see the refuge

is to kayak or canoe through its three paddling trails; pick up a waterproof map at the visitors' center. Alternatively, bring or rent a bike

and cycle along the more than fifty miles of country roads in and around Blackwater, including three cycling loops that follow flat, low-traffic roads.

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*Captain John Smith
1612*



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Loy's Station, in Frederick County, is one of eight covered bridges remaining in Maryland

Frederick County is the perfect place to explore our Civil War heritage.



In Kent County, you'll find a treasured national wildlife refuge situated along the Atlantic Flyway

FREDERICK COUNTY

HISTORIC FREDERICK COUNTY IS LESS THAN ONE HOUR FROM Washington, D.C., Baltimore, and nearby Gettysburg, Antietam, and Harpers Ferry. Known for its historic sites and Civil War heritage, the county was the location of the Battle of Monocacy in 1864, and its towns were occupied by troops who fought at Antietam and Gettysburg. Two Maryland Civil War Trail driving tours (download at civilwartraveler.com/Maryland/index.html) cross the county, enabling you to follow the troops' steps. As a result of these battles, Frederick became a major Civil War

hospital center; learn more about this part of the county's history at the National Museum of Civil War Medicine. Visit Monocacy National Battlefield's brand-new visitor center, with state-of-the-art exhibits that broaden the context of this one-day battle into the entire Civil War. If you prefer the great outdoors, check out one of Frederick County's ninety parks,

or hike along two well-known trails that pass through the county: the Appalachian Trail, which crosses through Frederick's eastern part (enter at Gathland State Park), and the C&O Canal National Historic Park trail, which takes you along the path of the early nineteenth-century canal. Catoctin Mountain Park, part of the Blue Ridge Mountains, offers fly-fishing as well as twenty-five miles of scenic trails, and you may stay at a WPA built cabin or national historic campsite. In nearby Thurmont, hike to the 78-foot cascading waterfall at Cunningham Falls State Park.

KENT COUNTY

A PENINSULA ON THE EASTERN Shore, Kent County is where fresh and salt water meet, and is a haven for fishing and boating, cycling, birding, and exploring nature. The tidewater tributaries of the Chesapeake course through Kent's unspoiled farmlands, and the waterfront towns, once great shipbuilding and fishing communities, preserve the feel of an earlier, more serene way of life. All throughout the county's tidal shores, you'll see a plethora of aquatic birds including ducks, geese, kingfishers, herons, ospreys, and bald eagles. The estuaries also offer ideal spawning conditions for many fish species, including alewife, shad, blue fish, perch, oysters, the blue crab, and striped bass, known locally as rockfish. You'll find much of the habitat characteristic of the Chesapeake region, from pine forests to meadows to tidal wetlands, on the Eastern Neck National Wildlife Refuge. This island features an observation platform above shoal waters teeming with ducks, geese, tundra swans, and other migrating waterfowl. You'll also see ospreys, deer, and red foxes.

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WORCESTER COUNTY**MARYLAND'S ONLY SEASIDE COUNTY,**

located on its Eastern Shore, Worcester is known for the sandy resort of Ocean City and the wild ponies of Assateague. The county claims to have the best birding in the state, with more than 350 recorded species, from pelicans to peewees, kingbirds and cuckoos, and herons, harriers, and eagles. Worcester owes much of this abundance to a diversity of habitats—including barrier island, a cypress swamp, old forests, and tidal wetlands—and all are easily accessible. With its coastal habitats and temperate climate, the county is the northernmost breeding range of several southern species including the brown pelican; it's also the southernmost winter location of sightings of northern species such as purple sandpipers and great cormorants. Don't leave Worcester without a visit to the famous herd of ponies

at the Assateague Island State Park and National Seashore. Hike the three nature trails: Life of the Dunes Trail, Life of the Marsh Trail, and Life of the Forest Trail (the last two are handicap accessible). Bike along the island's designated bike trail or canoe the back waters of Sinepuxent Bay. You might stay in nearby Ocean City (sample the state's best French fries), at a bed-and-breakfast in the Victorian-era town of Berlin, or make your base in pretty and historic Snow Hill, near the Pocomoke River. As if that weren't enough, Worcester also has more than a dozen championship golf courses.



Worcester boasts some of Maryland's best birding, a herd of wild ponies along the Assateague shore, and more than a dozen championship golf courses

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Fifty years ago this month, the U.S.S.R. launched Sputnik 1, the world's first Earth-orbiting artificial satellite. Shocked into action, the U.S. ramped up its space program—and its science education.

By Neil deGrasse Tyson

Sputnik 1, above right, the first artificial satellite, 1957; Yuri Gagarin, below, the first person in space, 1961

One floodlit midnight in early October 1957, beside the river Syr Darya in the Republic of Kazakhstan—while office workers in New York were taking their afternoon break—Soviet rocket scientists were launching a two-foot-wide, polished aluminum sphere into Earth orbit. By the time New Yorkers sat down to dinner, the sphere had completed its second full orbit, and the Soviets had informed Washington of their triumph: *Sputnik 1*, humanity's first artificial satellite, was tracing an ellipse around Earth every ninety-six minutes, reaching a peak altitude of nearly 600 miles.

The next morning, October 5, a report of the satellite's ascent appeared in *Pravda*, the ruling Communist Party's official newspaper. ("Sputnik," by the way, simply means "satellite" or, more generally, "fellow traveler.") Following a few paragraphs of straight facts, *Pravda* adopts a celebratory tone and ends on a note of undiluted propaganda:

The successful launching of the first man-made earth satellite makes a most important contribution to the treasure-house of world science and culture. . . . Artificial earth satellites will pave the way to interplanetary travel and apparently our contemporaries will witness how the freed and conscientious labor of the people of the new socialist society makes the most daring dreams of mankind a reality.

The space race between Uncle Sam and the Reds had begun. Round one had ended in a knock-out. Ham radio operators could track the satellite's persistent beeps at 20,005 megacycles and vouch for its existence. Bird-watchers and stargazers alike could see the shiny little ball with their binoculars.

And that was only the beginning: the Soviet Union won not only round one but nearly all the other rounds as well. Yes, in 1969 America put the first man on the Moon. But let's curb our enthusiasm and look at the Soviet Union's achievement during the first three decades of the Space Age.

Besides launching the first artificial satellite, the Soviets sent the first animal into orbit (Laika, a stray dog), the first human being (Yuri Gagarin, a military pilot), the first woman (Valentina Tereshkova, a parachutist), and the first black person (Arnaldo Tamayo-Méndez, a Cuban military pilot). The Soviets sent the first multiperson crew and the first international crew into orbit. They made the first space walk, launched the first space station, and were the first to put a manned space station into long-term orbit.

They were also the first to orbit the Moon, the first to land an unmanned

capsule on the Moon, the first to photograph earthrise from the Moon, the first to photograph the far side of the

Moon, the first to put a rover on the Moon, and the first to put a satellite in orbit around the Moon. They were the first to land on Mars and the first to land on

Venus. And whereas *Sputnik 1* weighed 184 pounds and *Sputnik 2* (launched a month later) weighed 1,120 pounds, the first satellite America had planned to send aloft weighed slightly more than three pounds. Most ignominious of all, when the United States tried its first actual launch after *Sputnik*—in early December 1957—the rocket burst into flames at the (suborbital) altitude of three feet.

In July 1955, from a podium at the White House, President Eisenhower's press secretary had announced America's intention to send "small" satellites into orbit during the International Geophysical Year (July 1957 through December 1958). A few days later a similar announcement came from the chairman of the Soviet space commission, who maintained that the first satellites shouldn't have to be





Laika, first animal in space, 1957



Alexei Leonov, first space walker, 1965

all that small and that the U.S.S.R. would send up a few of its own in the “near future.”

And so it did.

In January 1957, the Soviet missile maven and ultra-persuasive space advocate Sergei Korolev (never referred to in the Soviet press by name) warned his government that America had declared its rockets to be capable of flying “higher and farther than all the rockets in the world,” and that “the U.S.A. is preparing in the nearest months a new attempt to launch an artificial Earth satellite and is willing to pay any price to achieve this priority.” His warning worked. In the spring of 1957, the Soviets began testing precursors to orbiting satellites: intercontinental ballistic missiles that could loft a 200-pound payload.

On August 21, their fourth try, they succeeded. Missile and payload made it all the way from Kazakhstan to Kamchatka—some 4,000 miles. TASS, the official Soviet news agency, uncharacteristically announced the event to the world:

A few days ago a super-long-range, intercontinental multistage ballistic missile was launched. . . . The flight of the missile took place at a very great, hitherto unattained, altitude. Covering an enormous distance in a short time, the missile hit the assigned region. The results obtained show that there is the possibility of launching missiles into any region of the terrestrial globe.

Strong words. Strong motives. Enough to spook any adversary into action.

Meanwhile, in mid-July the British weekly *New Scientist* had told readers about the Soviet Union’s growing pri-

macy in the space race and described the orbit of an impending Soviet satellite. But America took little notice.

In mid-September Korolev told an assembly of scientists about the imminent launches of both Soviet and American “artificial satellites of the Earth with scientific goals.” Still America took little notice.

Then came October 4.

Sputnik 1 kicked many heads out of the sand. Some people in power went, well, ballistic. Lyndon B. Johnson, at the time the Senate majority leader, warned, “Soon [the Soviets] will be dropping bombs on us from space like kids dropping rocks onto cars from freeway overpasses.” Others were anxious to downplay both the geopolitical implications of the satellite and the Soviet Union’s capabilities. Secretary of State John Foster Dulles wrote that the importance of *Sputnik 1* “should not be exaggerated” and rationalized America’s nonperformance thus: “Despotic societies which can command the activities and resources of all their people can often produce spectacular accomplishments. These, however, do not prove that freedom is not the best way.”

On October 5, under a page-one banner headline (and alongside coverage of a flu epidemic in New York City and the showdown in Little Rock with the segregationist Arkansas governor, Orval Faubus), *The New York Times* ran an article that included the following reassurances:

Military experts have said that the satellites would have no practicable military application in the foreseeable future. . . . Their real significance would be in providing scientists with important new information concerning the nature of the sun, cosmic radiation, solar radio interference and static-producing phenomena.

What? No military applications? Satellites were simply about monitoring the Sun? Behind-the-scenes strategists thought otherwise. According to the summary of an October 10 meeting between President Eisenhower and his National Security Council, the U.S. had “always been aware of the cold war implications of the launching of the first earth satellite.” Even America’s best allies “require assurance that we have not been surpassed scientifically and militarily by the U.S.S.R.”

Eisenhower didn’t have to worry about ordinary Americans, though. Most remained unperturbed. Or maybe the spin campaign worked its magic. In any case, plenty of ham radio operators ignored the beeps, plenty of newspapers ran their satellite articles on page three or five, and a Gallup poll found that 60 percent of people questioned in Washington and Chicago expected that the U.S. would make the next big splash in space.

America’s cold warriors, now fully awake to the military potential of space, understood that U.S. postwar prestige and power had been challenged. Within a year, money to help restore them would be pumped into science education, the education of college teachers, and research useful to the military.

Back in 1947, the President’s Commission on Higher Education had proposed as a goal that a third of America’s youth should graduate from a four-year college. The National Defense Educa-



Valentina Tereshkova, first woman in space, 1963

Agency, or DARPA, was born the same year (and so was I).

All those initiatives and agencies funneled the best American students into science, math, and engineering. The government got a lot of bang for its buck; graduate students in those fields, come wartime, got draft deferments; and the concept of federal funding for education got validated.

Instead of being put on trial at Nuremberg for war crimes, von Braun became America's savior, the progenitor and public face of the U.S. space program. His first high-profile task was to provide the first rocket for the first successful launch of America's first satellite. On January 31, 1958—less than

tion Act of 1958 was a key, if modest, push in that direction. It provided low-interest student loans for undergraduates as well as three-year National Defense Fellowships for several thousand graduate students. Funding for the National Science Foundation tripled right after *Sputnik*; by 1968 it was a dozen times the pre-*Sputnik* appropriation. The National Aeronautics and Space Act of 1958 hatched a new, full-service civilian agency called the National Aeronautics and Space Administration—NASA. The Defense Advanced Research Projects

But some kind of satellite, built by any means necessary, had to be launched a.s.a.p. Luckily, during the closing weeks and immediate aftermath of the Second World War, the U.S. had acquired a worthy challenger to Sergei Korolev: the German engineer and physicist Wernher von Braun, former leader of the team that had developed the terrifying V-2 ballistic missile for the Nazis. We also acquired more than a hundred members of his team.



Salyut 1, first space station, 1971

four months after *Sputnik 1*'s round-the-world tour—he and his rocketeers got the thirty-pound *Explorer 1*, plus

Continued on page 44



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Lucy Goes Walkabout

The travels of a celebrated fossil highlight the vitality of Ethiopian paleoanthropology.

By Ian Tattersall

The world's most famous hominid fossil has taken up temporary residence (until next April 20) at the Houston Museum of Natural Science, as the star attraction of the exhibition "Lucy's Legacy: The Hidden Treasures of Ethiopia." An early hominid and a distant cousin of modern humanity, Lucy died some 3.18 million years ago in what is now the rugged Afar region of northern Ethiopia. At the time of her discovery three decades ago, Lucy was the most complete skeleton known of any hominid predating the Neanderthals—mere parvenus, by comparison. And even though other fossils have since made the headlines, Lucy's name still retains its magic, and her diminutive skeleton (she would have stood a little more than three feet tall) is an instantly recognizable symbol of our deep biological roots.

Lucy's sojourn in Houston is not her first visit to the United States. Following her unearthing by the paleoanthropologist Donald C. Johanson

and his colleagues in 1974, Lucy spent the next five years on loan to the Cleveland Museum of Natural History, then Johanson's home institution. There the requisite scientific descriptions were prepared, and molds made so that casts could be distributed for study and exhibition. Since 1980, however, Lucy has resided in Addis Ababa, in a vault at the National Museum of Ethiopia, only seeing the light of day for the benefit of visiting scientists and the occasional dignitary.

Dinosaur bones and many other fossils routinely hit the road, but fossils of extinct hominids tend to be treated as sacrosanct, never allowed to leave their home institutions, let alone their countries of origin. That is regrettable, in part because such fossils are the patrimony of all humankind. Furthermore, paleontology is quintessentially a comparative business: no fossil can be satisfactorily understood in isolation from the wider record.

In 1984, for example, the American Museum of Natural History in New York City held a one-time exhibition called "Ancestors: Four Million Years of Humanity," which brought together fifty specimens from around the globe. Before the exhibition opened, several dozen scientists participated in three days of detailed comparative examinations and a two-day symposium. The experience was a revelation to scholars: for the only time in their lives, they could see these central objects of their study side-by-side. The proceedings led

to a volume of scholarly papers, whose conclusions are still being cited.

Still, somebody has to take responsibility for caring for the irreplaceable vestiges of our vanished past. As chance would have it, the first 5 million years or so of hominid history unfolded uniquely in Africa, and the nations where the fossil evidence is found can take special pride in preserving them on their home soil. But few governments on that continent have the luxury of munificently supporting such abstract concerns as paleontology. If the wider world wants to know the details of early human history, it must commit the necessary resources.

Early major paleoanthropological explorations in Ethiopia followed the pattern typical throughout Africa: outsiders funded and directed the work. But the initial impetus for it was national rivalry. The biographer Virginia Morrell records that in 1965, the Kenyan paleontologist Louis Leakey ran into Ethiopia's Emperor Haile Selassie at a diplomatic event in Nairobi. In the course of their conversation Haile Selassie reportedly asked, "Dr. Leakey, why has my country got no fossils like you find in Tanzania and Kenya?" Leakey replied that the fossils were surely there; all that was lacking was the Ethiopian government's permission to go and look for them. Predictably enough, an official invitation was soon forthcoming to organize an international fossil-hunting expedition in southern Ethiopia.

From that flowed the investigations in the Afar region of the north, where Lucy, along with many other fossils of her bipedal species, *Australopithecus*



Skull of "Lucy's Baby," a three-year-old *Australopithecus afarensis*, was discovered in 1999 by an Ethiopian paleoanthropologist.

afarensis, was unearthed. Today the arid badlands of the region are among the most hostile environments on earth. But three or four million years ago the area offered a mosaic of environments that ranged from forest to woodlands to savanna. The place was an ideal locale in which primates whose ancestral forest habitats were being fragmented by climatic drying could experiment with new lifeways that substantially increased their time on the ground [see illustration on cover of this issue].

The fossils of *A. afarensis* and potential future finds were destined from the start for the National Museum of Ethiopia, transforming the institution into a magnet for investigators worldwide and a center for training home-grown paleontologists. In the 1970s local people were employed as collectors and guards, but there were no Ethiopian paleontologists. Today that is no longer the case.

There's no more striking exemplar

of the transformation than Zeresenay "Zeray" Alemseged, the Ethiopian paleontologist who last year announced the discovery of a skeleton of a three-year-old *A. afarensis* at Dikika, a site not far from where Lucy was found. Now an investigator at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, Alemseged trained in his home country and in France, and earned a postdoctoral fellowship at the Institute of Human Origins, Johanson's center at Arizona State University in Tucson.

Even more complete than Lucy herself, the 3.3-million-year-old Dikika fossil was inevitably dubbed Lucy's Baby (though it lived and died long before Lucy was born). It is exquisitely preserved; the hitch is that the matrix enclosing the fossil is rock-hard, fiendishly difficult to remove without damaging the bones. But Alemseged's painstaking partial removal of the matrix has already confirmed that the species walked upright while on the ground,

yet retained characteristics, particularly of the upper body, that would have helped it move around in trees.

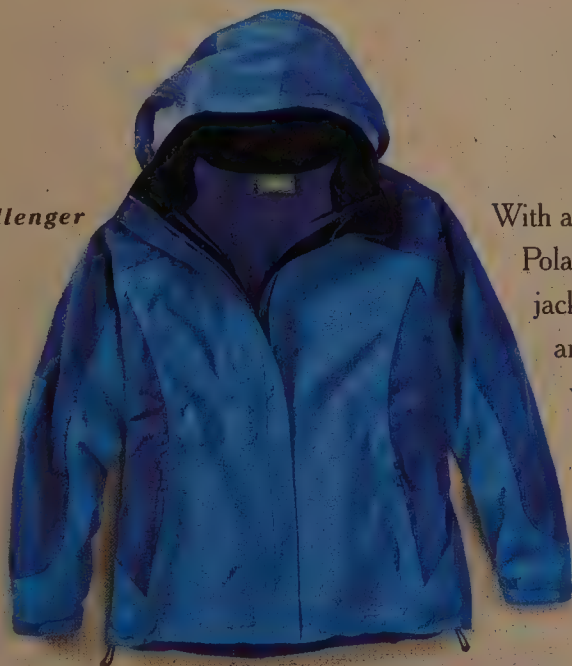
The preliminary observations raise once again the question of why hominids became bipedal in the first place. Some have argued that the main advantage of terrestrial walking is that it frees the hands, enabling hominids to carry and manipulate objects. Others have calculated that walking is energetically more efficient. A third group has pointed out that you can spot potential predators from farther away. And it has been engagingly argued that an upright stance helps minimize the impact of the Sun's heat when away from the shelter of trees.

The key is that once a creature is standing upright, it would enjoy all those potential advantages (as well as suffer various disadvantages). And I find it hard to imagine that an arboreal quadruped would ever adopt such an unac-

Continued on page 43

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Deep Trouble

Fishermen have been casting their nets into the deep sea after exhausting shallow-water stocks. But adaptations to deepwater living make the fishes there particularly vulnerable to overfishing—and many are now endangered.

By Richard L. Haedrich



The deck was covered with fish. I'd never seen anything like it. There were long, slender eels, black sharks, pale rays, silvery grenadiers with long, pointy tails, and great black things with huge, dark eyes. We'd needed the biggest winch on our research vessel to haul them up from the bottom of the North Atlantic, some

5,000 feet below the surface and a hundred miles east of New York City. My colleagues and I waded into the catch and began sorting the various species into piles, marveling at their extraordinary forms.

I was a young fish biologist at the time, part of a team studying the distribution of fishes elsewhere in the deep sea: not at the bottom but in the midwaters, a part of the water column above the seafloor. We regularly trawled the midwaters at various depths down to 3,500 feet. After towing a net for as long as three hours, we'd come up with a sample at times no bigger than a teacupful—or, if we were lucky, a small bucketful—of sardine-size creatures. But a break in that routine had given me a chance to see what lives even

bottom-dwelling animals typically grow slowly, delay reproduction, and live long lives—adaptations to making a go of it in the cold, dark, nutrient-poor waters of the deep-sea floor. But those same attributes make the fishes particularly vulnerable to a new stress: deep-sea fishing. As populations of shallow-water fishes have crashed, the global demand for seafood has led to rapid overfishing of the bottom, along with the habitat destruction that bottom-trawling wreaks. We estimate that more than 20 percent of the northwest Atlantic's deep-sea fish species have declined so seriously that they should be considered for threatened or endangered status. And the same thing is happening the world over: deep-sea fishes everywhere—from Greenland halibut near the Arctic Circle to Chilean sea bass off Antarctica—are being hunted to the verge of extinction. If I were to return to that spot in the North Atlantic where I made my first bottom trawl, the deck would no longer be covered with fishes. I'd be lucky to catch a bucketful.



deeper, and so we broke out the bottom-trawl net. Even as the ship's crane swung the bag, or "cod end" of the net, aboard, I could see that bottom samples were entirely different. The net was bulging, and when the knot cinching it shut was undone, a great swirl of mud and sea creatures had spilled onto the deck.

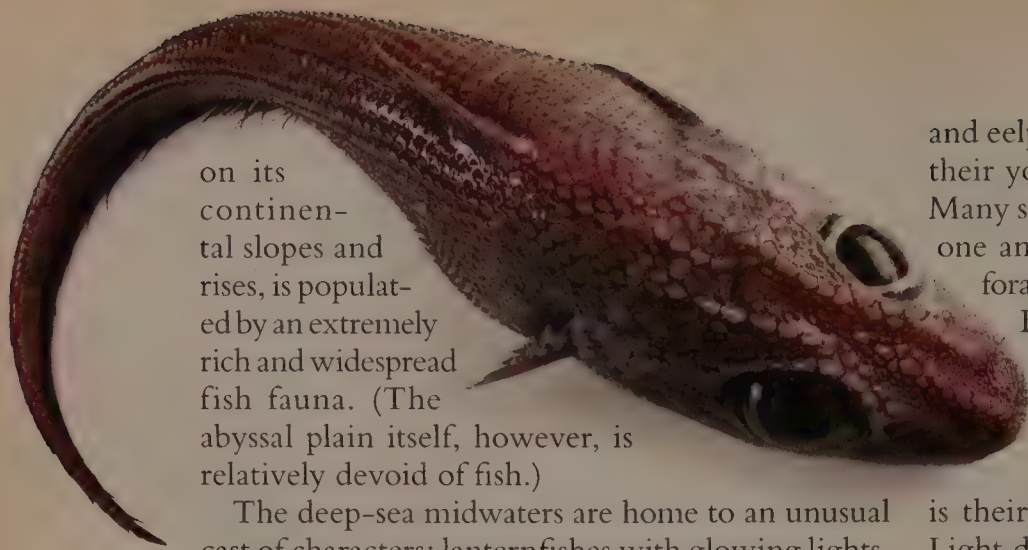
And the fishes! Not a cup or a bucket of small fry, but more like half a ton of strange and wonderfully big fishes. I was hooked. That first bottom trawl, forty years ago, launched a lifelong career in research and teaching about the fishes that live at the bottom of the ocean.

My colleagues and I have learned that those

The deep sea does not begin at the beach; it encompasses the waters from surface to seafloor that lie beyond the continental shelf. Shallow coastal waters overlie the shelf, which can extend a hundred miles or so from shore. There, at the true edge of the continent, where the water is about 600 feet deep, the topography steepens. The seafloor plunges some 6,000 feet down the continental slope, then declines more gently down the continental rise and onto the abyssal plain. The average depth of the plain is 13,000 feet, but it is interrupted by trenches as deep as 30,000 feet, or by mountainous ridges and volcanic seamounts, some of which reach the surface to form island chains, such as Hawai'i [see inset of illustration on page 31].

Early ocean explorers thought conditions in the deep sea were too harsh to support life. In fact, though, the deep sea, both in its midwaters and

Roundnose grenadiers pour from a net aboard a bottom trawler 400 miles off Ireland (facing page). Grenadiers, like most deep-sea fishes, mature slowly and live long. Overfished populations can thus take decades or even centuries to replenish themselves. Orange roughy, top right, which may live to be 150, and Chilean sea bass, above, which can live to at least 70 and possibly much longer, have been severely depleted in recent decades. (Fishes are not shown to scale.)



on its continental slopes and rises, is populated by an extremely rich and widespread fish fauna. (The abyssal plain itself, however, is relatively devoid of fish.)

The deep-sea midwaters are home to an unusual cast of characters: lanternfishes with glowing lights, silver hatchetfishes with telescopic eyes, and viperfishes with tremendous fangs, among many others. But midwater fishes are sea monsters in appearance only: most are no longer than a foot. Because of their diminutive size and relatively low density, no extensive deep-sea midwater fishery has yet developed.

The continental slopes are another story. At depths between 600 and 6,000 feet, the slopes are where the fishing happens. Animals living there are bigger and more abundant than in the midwaters of equal depth, largely because the bottom provides both structure and a collection place for food particles falling from the productive surface waters.

Yet despite the increasingly heavy commercial fishing there, much remains unknown about continental slopes. Worldwide, just a fraction of 1 percent of their total area has been explored, and investigators have only recently begun to appreciate the complexity of slope habitats. In part, that's because most of the slopes appear to be featureless expanses of dull mud. Only a few areas, such as the hot vents of tectonically active ridges and trenches, were acknowledged as dynamic and structured ecosystems. But it turns out that even the mud is home to thriving populations of crustaceans, sea stars, urchins, worms, and myriad other creatures. Recently, even deep-sea coral beds have been discovered to be widespread on the world's continental slopes [see photographs on pages 32 and 33]. They play host to a highly diverse and little-known fauna, and it is likely that their tangled structure provides protective cover to juvenile fishes.

The fishes of the continental slope display numerous adaptations to deepwater living, which include cold tolerance; longevity; and enhanced vision, hearing, and sound production for making their way in darkness. Certain species, such as deepwater rays, rockfishes,

and eelpouts, bear live young or build nests to give their young a head start in a tough environment. Many slope dwellers are relatively large—between one and three feet long—which enables them to forage over broad areas. Many also live in schools.

Both their size and schooling behavior have made certain species attractive targets of fisheries—which has in turn brought about the fishes' undoing.

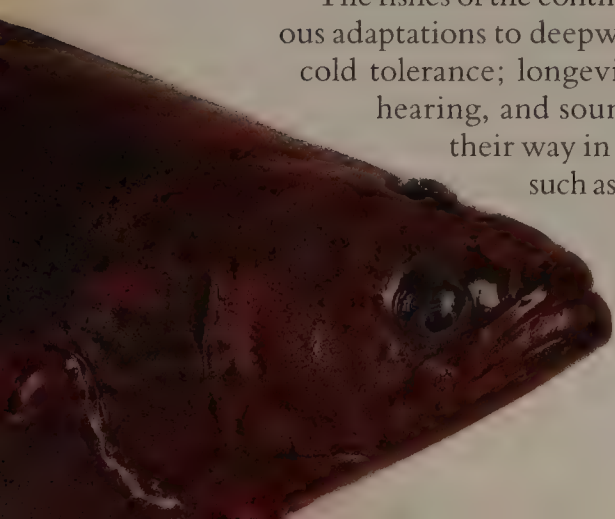
The main reason for their vulnerability is their slow growth rate, a fact of life at depth. Light does not penetrate to the continental slope, so no photosynthesis takes place there, and there is no in situ food production. Virtually all the energy for the slope's food chain must be imported. Most comes in as debris raining from above—from dead phytoplankton to dead whales. Even so, there isn't much. Throughout the deep sea the available food declines quickly with depth, increasing somewhat on the seafloor itself.

As a result, the abundance, biomass, and metabolic rates of organisms also decline. With a low metabolic rate, a fish takes longer to grow to maturity: a cod on the shallow continental shelf matures in four to seven years, whereas a grenadier on the continental slope may take eighteen years. By the time many deepwater fishes are big enough to be worth catching, they are older than your grandmother: the fillet of orange roughy you order at a restaurant could easily come from a fish born before the invention of the automobile.

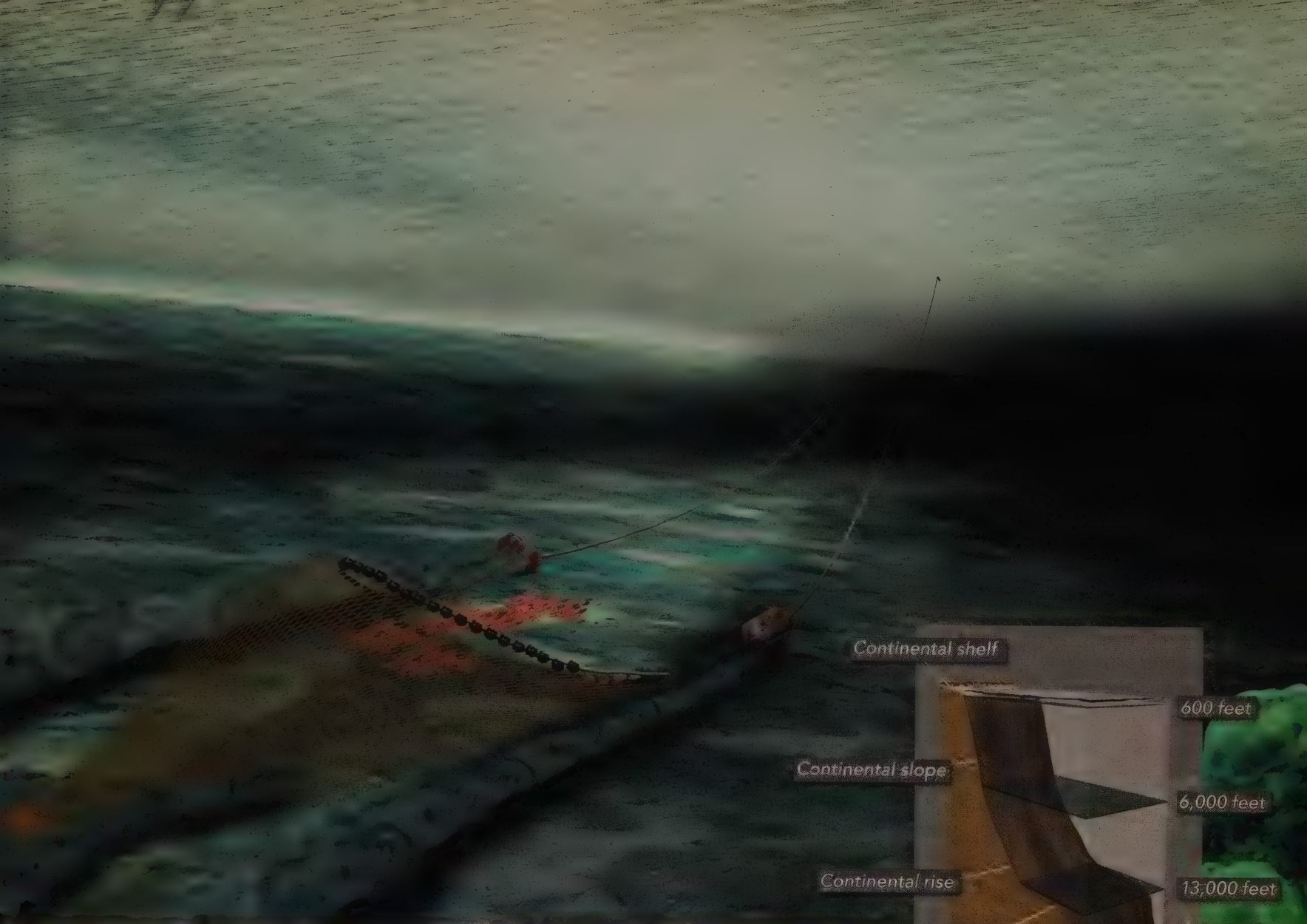
Thus populations turn over quite slowly. A fishery naturally targets the largest individuals, and so can quickly wipe out most of a population's mature, reproductive fish, which can take decades to replenish. Add to that the possibility that some slope fishes might only spawn once at the end of their long lives, and you have a recipe for extinction.

Except for a few special cases, deep-sea fisheries are all of recent vintage. In the early 1970s Soviet fishermen became the first to systematically locate and exploit continental-slope fishes. But despite glowing accounts of the tastiness of the fishes—blue hake, deepwater sharks, grenadiers, and slickheads, among others—a strong international market never developed. The fishery instead supplied immense quantities of low-quality product to the former Eastern Bloc, where cheap protein was in demand. State-sponsored fleets from the Soviet Union—and later, from its former republics—aggressively fished the northwest Atlantic and various other regions into the 1990s; some are still active today.

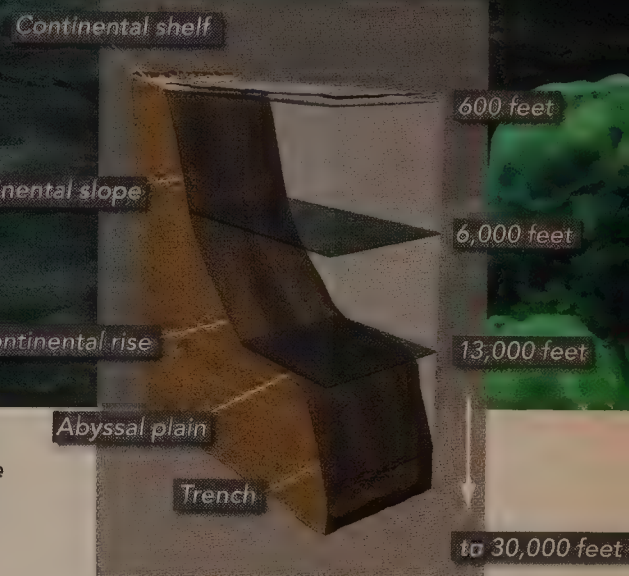
Worldwide, the expansion to the deep sea stems directly from the severe depletion of shallow-water



Two aggressively exploited deep-sea fishes: roughhead grenadier, top, and Greenland halibut, left. (Fishes are not shown to scale.)



Bottom trawling gear, depicted here schematically, is dragged across the seafloor. Fish in its path are herded into the net, which can span the area of several football fields. A chain at the bottom of the net connects two five-ton steel plates, which keep the net open. The gear can weigh fifteen tons and disturbs or destroys any features in its path. The cross-section (inset) shows the depth profile of the seafloor; the vertical dimension is exaggerated for clarity.



fisheries. In the northwest Atlantic, for instance, the collapse of cod in the early 1990s became one of the most dramatic fish-stock crashes of all time. But the industry found a substitute in the deepwater Greenland halibut. Predictably, that species is now in trouble throughout the Atlantic. Elsewhere, deep-sea fisheries have developed for numerous species, including icefish in the waters off Antarctica, Patagonian toothfish off Argentina and Chile, hoki off Australia and New Zealand, black oreos off New Zealand, thornyheads near Pacific seamounts, and giant rattails in the northwest Pacific.

The deep-sea orange-roughy fishery near Australia is a prime example. It was developed to satisfy the middle-American market for a bland, white fish. Even the name was picked through careful supermarket research (its original moniker, the slimehead, sounded far less appealing). And when that fishery began its inevitable decline, the industry moved on to another deep-sea species, the Patagonian toothfish.

It was renamed the Chilean sea bass, even though it is neither a bass nor exclusively Chilean. It, too, has now suffered sharp declines.

The bottom-trawling gear for deepwater fishing is basically the same as the gear deployed in shallow waters, but on an enormous scale. Factory ships longer than 300 feet can hold 1,000 tons of fish and stay at sea for 300 days a year. Massive winches and cables are needed to reach the slope bottom, ten times deeper than the continental shelf. The net itself is woven from heavy polypropylene line and can span the area of several football fields [see illustration above]. A pair of steel plates called doors, weighing as much as five tons each and connected to the net with heavy cables, spread the net open under water. The doors and cables scrape along the ocean floor and herd fish into the net—as much as twenty tons in each haul. The entire rig can weigh fifteen tons, and is dragged across the

bottom for several hours at a clip of four miles an hour or more. Little more than finely ground rubble remains on the seafloor in its wake.

In theory, a fishery should be managed sustainably, taking no more each year than what reproduction replaces. Thus the size of the take is determined by numerical models that can estimate future populations. Accurate estimates depend on accurate information about a species' age at maturity and its growth rate. Those numbers depend, in turn, on survey data on abundance and body size—a proxy for age.

Yet none of those data existed reliably for deep-sea fishes as their fisheries developed. Managers set catch quotas essentially by guesswork, relying on their knowledge of shallow-water species. They took no account of the far slower turnover rates in a typical population of deep-sea fishes. And even when fisheries could not catch enough fish to meet their quotas, as was the case with the roundnose grenadier for more than twenty years, the quotas were not decreased.

Unfortunately, circumstances today have not much changed. Most deep-sea fisheries, as in decades past, are little more than mining operations that run until they exhaust their target populations and collapse. Then they move on to another species.

In 1987 my students and I began to study the ecology of fisheries. As continental-shelf stocks declined and fisheries moved into deeper water, we followed them out to sea. In 2002 we turned our attention seriously to understanding how fishing had affected deep-sea fishes.

We began by examining the roundnose grenadier and the roughhead grenadier, or onion-eye, using scientific survey data assembled annually by the Canadian government. Soviet trawlers and others had been fishing the two species off Canada since 1970, but catches had plummeted in recent years. Sure enough, we discovered that their populations had declined by as much as 99 percent since 1978, precipitously enough to qualify them for endangered status.

Decline rates are one thing, but the big question both ecologists and fishery managers ask is, how

long will species take to recover from exploitation? There is a widespread assumption that fish populations can still recover even after they have declined by 95 percent or more. But that rests on hope as much as on any solid evidence. And even taking an optimistic view, most species—even fast-growing continental-shelf species—will probably need decades, not years, to make a full recovery.

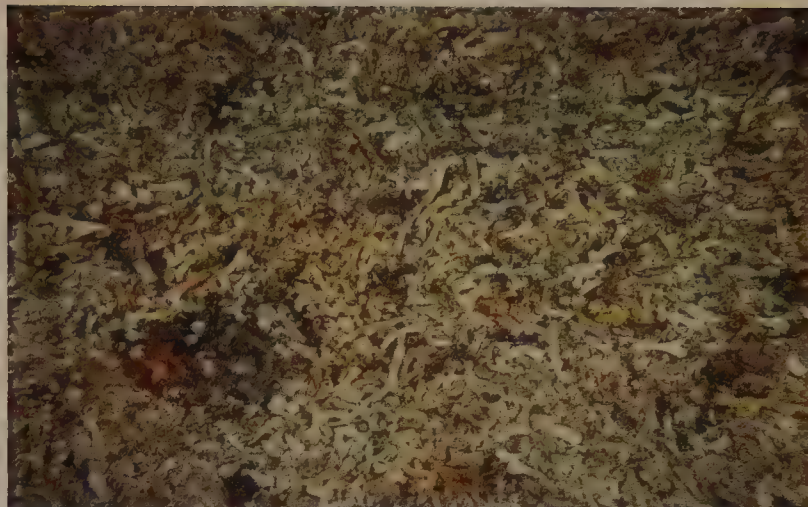
For the roundnose and roughhead grenadiers, even the minimal information required to make predictions about recovery times was not gathered until two decades after the fishery began. By that time, the fishery had collapsed, and populations of both species could qualify for endangered status. My colleagues and I calculated the grenadiers' recovery times on the basis of those data; they range from decades to more than a century, assuming no more fishing—not a surprising result, given those fishes' slow growth, delayed maturity, and long lives.



Large piece of deep-sea coral, unintentionally caught in the net of a bottom trawler, gets tossed back into the sea by a crew member. Deep-sea coral can take centuries to reach the size of the piece shown here, so destroying it could lead to the permanent destruction of any habitat that depends on it.

We have now extended our research on grenadiers to forty species of continental-slope fishes in the northwest Atlantic. (There are about sixty species in all, but we are limited to those for which there are enough data to determine changes in abundance.) It is worth noting that ours is the world's first ecosystem-wide assessment of the effects of fishing in the deep sea—the subject is so little researched. Eight of the forty species, we discovered, have declined so precipitously that they could be considered threatened or endangered. Another ten species have also declined, though not as much.

When we began the research, we had expected to find that large, free-swimming fishes, which are most susceptible to capture by bottom trawls, had suffered the most marked declines. But that was not the case. Rather, the declines were greatest among small species, including the Arctic eelpout, Scotian snailfish, and wolf eelpout. Those species live right on the bottom, often hiding among rocks. We suspect that habitat destruction by trawling, not entrapment in nets, played the leading role in their decline. And though that decline is worrisome enough in its own right, it may portend habitat



Living deepwater coral, above left, makes a sharp contrast with a similar area subjected to bottom trawling, above right. Recent surveys have shown that deepwater corals are widespread on the world's continental slopes. They form complex habitats, which are home to many animals, and they may serve as nurseries for deep-sea fishes.

destruction on a scale that could have repercussions throughout the ecosystem.

The fragile deepwater corals that create desirable habitat for many fish species are no match for the heavy trawls, either [see *photographs above*]. Recent studies have shown that the corals grow extremely slowly: a coral growing on the bow of the *Titanic*, photographed not long ago by a Russian submersible, is hardly two inches tall. Severely damaged deep-sea coral banks will probably take millennia to recover fully. So, in addition to the direct effect of the nets on fish populations, their unintended effect on habitats is so completely and enduringly destructive that the populations may never recover. The species are simply unlikely to survive long enough for their habitats to reestablish themselves.

Fortunately, governments are taking note of the scientific findings—both my own and those of others. Last year a resolution to ban trawling in international waters was debated in the UN General Assembly. It failed, but just barely: UN resolutions require unanimity, and a handful of nations—Iceland the most prominent among them—did not agree with the rest of the world.

Still, many countries are taking unilateral action to limit deep-sea trawling within their own exclusive economic zones (EEZs), the 200-mile-wide strip of ocean that lies just off a nation's shores. Virtually the entire Mediterranean Sea is now protected; Australia, the Azores, New Zealand, and the United States have set aside large regions where such fishing is off limits, as it is in the waters off Antarctica. Trawling bans are now in place over more than 4 million square miles.

That, of course, is a small fraction of the entire world ocean—the Pacific alone is 65 million square

miles—and even then the protected regions are hard to patrol. Enforcement is all but impossible in remote areas such as Antarctica. And illegal trawling is not the only threat: poaching, misreporting of catch and bycatch, and various other destructive practices are all too common. The prospects for conservation seem dim. Indeed, fishermen are already turning away from depleted deepwater fish stocks and casting their nets and traps further down the food chain. Deepwater shrimp and crabs have become the latest targets, a familiar story with a predictable end.

Fishing-industry representatives who resist efforts to regulate deep-sea fisheries argue that too little is known to make rational decisions. Declining fish populations, they maintain, probably just reflect natural cycles. But marine biologists nowadays know more than enough about deep-sea ecology and the biology of deepwater fishes to recommend good choices.

Fisheries must balance human needs with the imperatives of the ocean. For the deep sea, in particular, short-term economics must come into alignment with long-term biology—surely a predicament whose resolution is not beyond human ingenuity. We must all learn to live with fishing practices adapted to the laws of nature in the deep sea, just as the fish living there have adapted. Evolution sets the pace of life in accord with physical conditions, and in the deep sea that pace is slow. The pace of our fishing there would do well to match it. □

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Male jumping spider of the species *Evarcha culicivora* can be distinguished by its bright red face; the female's colors are duller (see photograph on page 37). The species' favorite prey is a female mosquito engorged with her recent blood meals.



Vampire Slayers of Lake Victoria

African spiders get the jump on blood-filled mosquitoes.

By Simon D. Pollard
and Robert R. Jackson

The diet of the East African spider *Evarcha culicivora* reminds us of a line from the 1931 film *Dracula*. Soon after Renfield, a visitor from England, arrives at Count Dracula's castle, he struggles to get through an unnaturally large spiderweb that spans a staircase. "The spider spinning his web for the unwary fly," observes the count, ominously. "The blood is the life, Mr. Renfield."

The lifeblood for *E. culicivora* also comes from unwary flies, but it is not the pale blood of the flies that the spider is after. Often enough it is what Dracula was alluding to—human blood. For our spiders suck blood from engorged female mosquitoes, flies that are the miniature vampires of the real world. Some mosquitoes harbor human blood, whereas others may be carrying the blood of other mammals, birds, frogs, lizards, and occasionally even fish.

E. culicivora is a jumping spider, one of 5,000 species belonging to the family Salticidae. The adult is no bigger than about a third of an inch long. Jumping spiders have excellent eyesight, which they use to good effect when hunting, but *E. culicivora* is the only jumping spider—in fact, the only predator of any kind—known to seek out blood-carry-

ing female mosquitoes as prey. When quiescent, it hides in the grass or in other vegetation close to the ground. When it feeds, though, the spider patrols more exposed areas where mosquitoes are apt to land: typically, the bases of tree trunks and the outer and interior walls of buildings.

The species is native to the region of Kenya and Uganda near Lake Victoria, Africa's largest lake. (The lake is also the second-largest freshwater lake in the world, after Lake Superior if you rank by area, or after Lake Baikal, if you rank by volume.) Lake Victoria brews two kinds of storm clouds: the inanimate ones that form high above the water and shed rain, and the astounding living ones—dark clouds as thick as a hundred feet that roll across both water and surrounding terrain—made up mostly of midges. Mosquitoes are only a minority presence in those teeming swarms of "lake flies."

The midges belong mainly to two families, the Chaoboridae, or phantom midges, and the Chironomidae, or nonbiting midges, neither of whose members feed on blood. So they will not satisfy the spider's appetite for blood. Nor will just any mosquito suffice. Male mosquitoes, which subsist entirely on nectar and other sources of sugar, are

bloodless. And the females are less appealing, too, if they have failed to find a blood meal. Yet *E. culicivora* is a consummate expert at finding the needle (a blood-engorged mosquito) in a haystack of insects that descend to buildings and tree trunks from the cloud of lake flies. How, we wondered, can the little spider do it?

To explore that and related questions, we established a spider-rearing facility and an experimental laboratory at the Thomas Odhiambo Campus of the International Centre for Insect Physiology and Ecology. The campus is situated in western Kenya in Mbita Point, a village of about 8,000 people on the shore of Lake Victoria. There, and in the Spider Quarantine Laboratory at the University of Canterbury in Christchurch, New Zealand, we have worked with a sizable research team attracted to the bloodlust of *E. culicivora*.

With Godfrey Sune in Kenya and Ximena Nelson in New Zealand, we designed experiments that could clarify how the spiders find suitable prey. In one set of experiments, the spiders had to choose by sight between blood-engorged female mosquitoes and bloodless prey such as lake flies, male mosquitoes, and female mosquitoes that had not had a blood meal. Instead of real prey, we made lures from dead insects, which were washed in alcohol and dried to remove any chemical cues. Then we mounted them in lifelike postures and coated them with a plastic aerosol spray to keep them stationary and intact. Each predator could view the lures lined up around the outside of its cage, a display not unlike the plastic-coated models of food items from the menu at a Japanese restaurant.

A human diner chooses by pointing. Each of our spiders had to indicate its choice by moving into one of a series of glass tubes that led from the spider's cage toward the various offerings. By sight alone, the spider usually chose the lure that represented a blood meal.

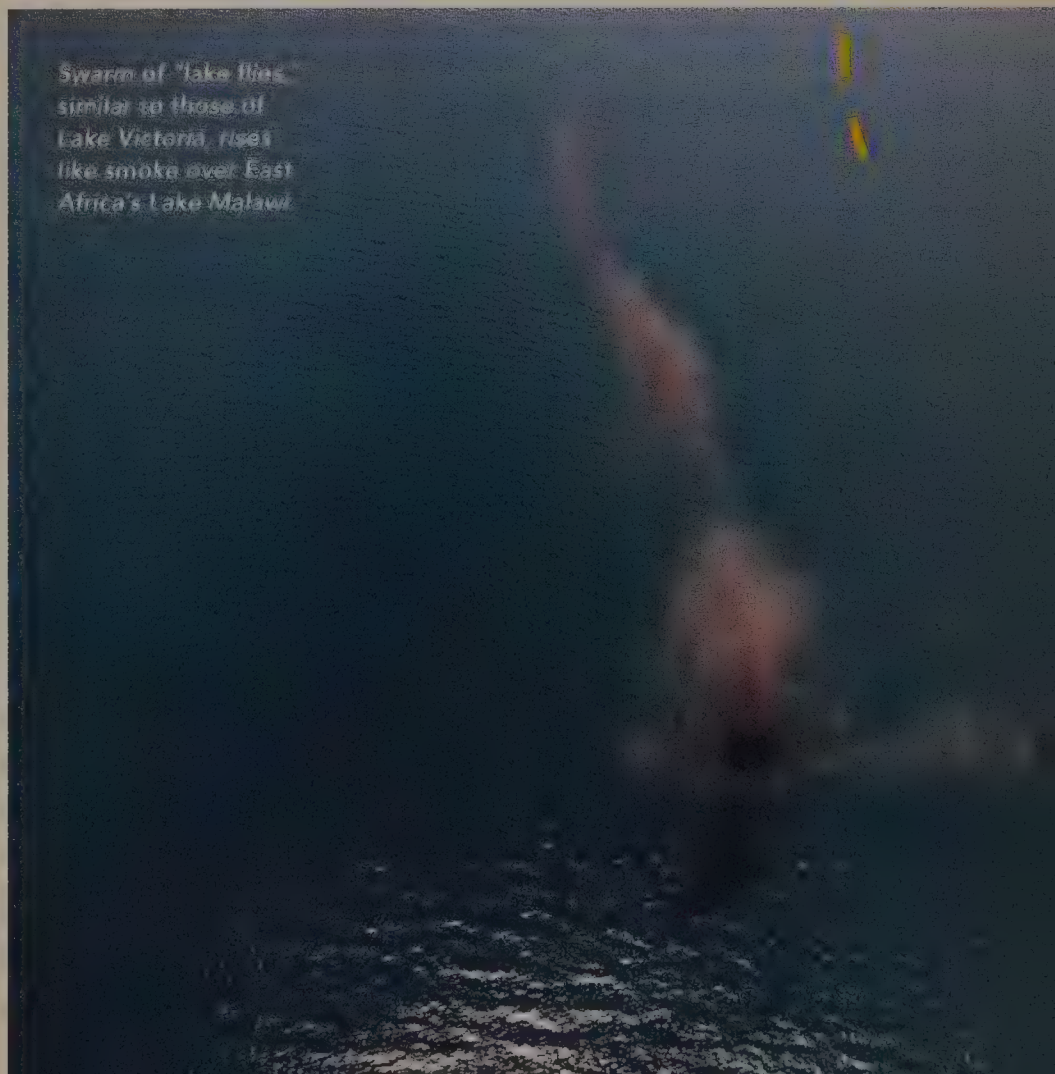
Jumping spiders have eight eyes: two large ones (by spider standards), which face forward and can determine the prey's size, shape, and color, and six smaller eyes along its sides that are excellent movement detectors. Amazingly, jumping spiders often make discriminations that rival human eyesight. The trade-off seems to come in processing speed. People decide what they're looking at in a glance, whereas a jumping spider may have to build up a picture by slowly searching the image for specific details.

We also showed that *E. culicivora* smells blood. In similar choice tests with hidden prey as lures, we found that our spiders moved toward air blowing across blood-carrying mosquitoes more often than toward air blowing across other targets.

We hypothesize that sight and smell work together as the spider looks for blood meals among the teeming masses of bloodless insects of similar size. Perhaps odor enables the spider to speed up its decision-making, if, say, the smell of a blood-carrying female mosquito primes it to detect that prey. Imagine being told you're going to see a painting if you look in a certain direction with binoculars. If you then see a certain characteristic smile, you'll probably guess, correctly, that you're seeing the *Mona Lisa*. Something similar could happen when the spider smells blood: seeing the shape of a distended abdomen (where a mosquito stores her blood meal) may be all the additional information the spider needs to know it has found what it is looking for.

We have been testing our hypothesis by adopting the laboratory methods of Dr. Frankenstein. Initially we created static monsters out of body parts from different mosquitoes, to learn what our spiders found most inviting. By attaching male mosquito antennae to a female body, for instance, we could test whether the spiders were attending to that particular feature. More recently we reanimated

Swarm of "lake flies" similar to those of Lake Victoria, rises like smoke over East Africa's Lake Malawi.





Juvenile jumping spider, above right, gets a blood meal by attaching its fangs to the thorax of a mosquito (partly obscured by the spider's body in the photograph), then drawing blood from the prey insect's abdomen. The spider's suction has already drawn blood through the spider's forebody (the cephalothorax) and its narrow "waist" into its own abdomen. The photomicrograph is magnified 13x.

our monsters by creating virtual mosquitoes, projected onto miniature movie screens for the spiders to watch. We digitally add and rearrange various body parts to see how the differences affect the spiders' responses. For example, a red undistended abdomen turns out to be more attractive than a distended but colorless one. The experiments suggest that *E. culicivora*, once primed by the odor of a blood-fed mosquito, just needs to see a distended, reddish abdomen to decide it has seen its favorite prey. The abdomen might be, for *E. culicivora*, the equivalent of the *Mona Lisa's* smile.

Drinking vertebrate blood taken from a mosquito may be an unusual way for a spider to get a meal, but all spiders are fluid feeders.

The typical spider routine is to immobilize an insect with venom injected from a pair of sharp fangs; the spider then secretes digestive fluids from its mouth into the prey's body. Inside the prey, the digestive fluids liquefy the internal tissues, which the spider then sucks out. An adult *E. culicivora* takes about an hour and a half to feed on a sugar-fed mosquito, but only about an hour to feed on a blood-fed one. Thus, by dining on a blood-fed mosquito, the spider enjoys the benefits of fast food. The mosquito's body is something like a paper wrapper around a hamburger: open it, and there's the meal, ready to eat.

The packaging for the blood is actually a bit more complicated than that. When a mosquito takes in a blood meal, its liquid bonanza is stored within a double container: the gut inside its abdomen. For an adult *E. culicivora* that presents hardly any barrier at all. Often at least twice the size of a mosquito, the adult spider rips into its prey, quickly crushing and rupturing the mosquito's fragile outer cuticle, as well as the gut membrane holding the blood. After mixing the blood with its digestive fluids, the spider sucks out the liquid and retires to digest its meal. The mauled corpse suggests an attack by a werewolf rather than by a suave Count Dracula.

Juvenile spiders, however, have a harder time extracting blood from the mosquito gut. A little juvenile attacks by sinking its fangs into the mosquito's thorax until the mosquito is subdued. Lacking large enough weaponry to tear into the body, the juvenile spider then places its mouth over the fang holes and cranks up its powerful stomach and pharyngeal muscles into sucking action. That draws fluid—though not yet blood—from the prey's thorax towards the spider's mouth and into its own digestive tract. The suction eventually ruptures the gut membrane encapsulating the blood. To an observer through a microscope, the scene inside the prey's body soon resembles a lazy, meandering river of blood and other nutrients moving toward the spider's mouth.

The small spider generates enough suction to draw fluids from as far away as the tip of the mosquito's abdomen. The body of the mosquito remains intact, but it collapses inwards from the suction, much as a soft cardboard carton of juice does when a person sucks out the contents with a straw. Eventually, however, the back pressure inside the corpse becomes too strong to suck against, and the juvenile spider relaxes its sucking muscles. Inside the mosquito, the lazy-river scene abruptly reverses into cascades, rapids, and turbulence, as most of the extracted fluid rushes back from the spider. This cycle of sucking and regurgitation repeats many times, as the mosquito's body is turned into an extension of the spider's own digestive tract.

The entire scene is often one of grotesque, comic images, as air and fluids rush in and out of the mosquito's body. For a moment the mosquito may inflate, its proboscis suddenly extending like a party noisemaker. The spider's digestive juices may also flake off the dark pigment covering the mosquito's compound eyes. The eyes, when emptied, become transparent, their little facets resembling cut crystal. Then when the fluid rushes back in, each eye looks like an empty punch bowl being filled with pink lemonade.

For the juvenile *E. culicivora*, all that is just part of the business of feeding. One might wonder why the spider doesn't move its mouth to the mosquito's abdomen, and shorten the distance over which blood has to be sucked. But apparently the repeated cycles of suction and regurgitation are effective in circulating digestive fluid throughout the mosquito's body. And there seems to be a good reason for feeding from the thorax: compared with the mosquito's abdomen, the thorax is a capsule with a rigid surface, providing a stable platform from which the liquid contents of the mosquito's abdomen can be efficiently pumped. In the end, the juvenile predator leaves behind a remarkably intact mosquito carcass.

Mosquitoes are good for delivering blood to *E. culicivora*, but of course they're bad for people. Many diseases are spread by mosquitoes, the most notorious being malaria, a disease caused by *Plasmodium*, a single-cell parasite. Human malaria depends on mosquitoes of the genus *Anopheles*. In Africa, one species in particular, *Anopheles gambiae*, is the malaria parasite's ultimate taxi for moving from person to person. For a mosquito, *A. gambiae* has an exceptionally long life span, and it takes its blood meals almost exclusively from people.

Finding a spider that singles out mosquitoes is welcome news in Africa, but wouldn't it be even better to find a spider that singles out *Anopheles*? Surely, though, that's asking too much. Or is it?

Adults and large juveniles of *E. culicivora* feed on a wide variety of mosquito species when they are hungry. But when they are well fed, they prefer *Anopheles*. In fact, the smallest of the juveniles—tiny ones in their first instar, or first stage of development, whose bodies are only four one-hundredths of an inch long—actually appear to single out *Anopheles*.

The reason is likely that the mosquito's habits make it relatively easy prey for such a small spider. *Anopheles* mosquitoes have a distinctive way of resting, with the abdomen tilted up. That characteristic posture is what the first-instar *E. culicivora* has evolved to exploit. On seeing a blood-filled *Anopheles* female, the small juvenile spider plots a path that will bring it around behind the mosquito and under its raised abdomen. From underneath, it jumps upward and brings down the mosquito.

Many people have trouble finding a mosquito in a crowd of lake flies, and even more trouble sorting out which mosquito is an *Anopheles*. Yet a first-instar *E. culicivora* can make those fine-grained discriminations with apparent ease. Perhaps deliberately breeding small armies of those young spiders could become a new secret weapon against the ancient scourge of malaria. □

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Adult female *E. culicivora* feeds on a female mosquito of the species *Anopheles gambiae*, the primary transmitter of the parasite that causes malaria in people.



What's Good for the Goose

A Wisconsin marsh offers a welcome rest stop to migrating birds.

By Robert H. Mohlenbrock

Egrets and other waterfowl are among the more than 200 bird species recorded at Horicon Marsh.

From mid-October through November, people flock to Horicon National Wildlife Refuge to observe flocks of Canada geese and other migrant species, as well as the resident birds. The thirty-three-square-mile refuge, in southeastern Wisconsin, encompasses the northern two-thirds of Horicon Marsh, the nation's largest freshwater cattail marsh (the southern

third is managed as a state wildlife area). The marsh is a favored stopover for a population of about a million Canada geese that nest near the southern edge of Hudson Bay in summer and fly south to wintering grounds in southern Illinois and nearby parts of the Mississippi valley.

The flight from Hudson Bay to Horicon Marsh is 850 miles. With a strong tailwind, the geese can average seventy miles an hour, so they can make the trip in as little as twelve hours. The first contingents arrive in mid-September; others make the journey in October or November. At the peak of the migration 200,000 or more Canada geese may be visiting the marsh at one time, "recharging their batteries." They feed almost exclusively on vegetation, not only marsh plants but also waste corn and other resources in the surrounding farmland.

Horicon Marsh owes its existence to glaciers that, during the most recent ice age, scoured a fourteen-mile-long depression into a layer of bedrock made up of relatively soft shale. When the ice began to recede, about 12,000 years ago, a lake of meltwater filled the depression, held in by a glacial deposit of earth and stones called a recessional moraine. Over time, what is now the Rock River flowed over that natural dam and so eroded it, draining the lake and leaving a vast wetland.

In prehistoric times, a succession of Native American peoples derived resources from the marsh. When European American pioneers arrived in the early nineteenth century, they encountered local settlements of Potawatomi and Ho-Chunk (Winnebago) Indians. In 1846 the European American settlers at the south end of the marsh built a dam on the Rock



Ruby-throated hummingbird

Marsh Aquatic plants scattered across the marsh include cattails, cursed crowfoot, hard-stem bulrush, marsh spikerush, marsh yellow cress, river bulrush, soft-stem bulrush, and water smartweed. Several species

of duckweeds float on the water; naiads and pondweeds, rooted in the marsh bed or drifting in the water, rise to just below the surface.

Streamside Trees along the streams include black wil-

low, box elder, eastern cottonwood, and silver maple. Among the shrubs are common elderberry, gray dogwood, ninebark, pussy willow, and red-osier dogwood. Cleavers, cow parsnip, hairy hedge nettle, late golden-

rod, meadow rue, panicled aster, spotted touch-me-not, and wood nettle are common wildflowers.

Moist woods American elm, box elder, and red ash are the dominant native trees,



established in 1927, and the rest of the marsh was purchased in 1941 to create the national wildlife refuge.

On the east side of the marsh, most conspicuously about a mile and a half north of the refuge visitor center, the adjoining land is elevated as a terrace, known locally as the Ledge. The Ledge owes its contour to an underlying formation of hard dolomite rock, which geologically is part of the Niagara Escarpment. The erosion-resistant rock follows a huge arc all the way from Horicon Marsh 500 miles eastward to Niagara Falls, which cascades over it. Along much of its route, the formation is either under water (at lakes Michigan, Huron, and Erie) or beneath the surface land. Here and there, however, the dolomite is exposed, most notably at Niagara Falls, which is receding upstream as the water wears the escarpment away.

Although most of the refuge is marshland, it also includes prairies, streambank plant communities, and woodland areas. At the north end of the refuge, originating at the Marsh Haven Nature Center, the 0.4-mile Egret Trail provides a good cross-section of the marsh from a floating boardwalk before leading into a moist forest. Hikers can sample drier woods in upland areas along the half-mile-long Red Fox Trail.

The spectacular fall goose migration makes October and November the most popular months for visiting the refuge. Flocks also stop here on their way north, from late February until the end of April, but the spectacle is more modest. At that time of year food is relatively scarce, and the geese, which must quickly gain weight

for the spring migration, spread out over a larger territory to feed.

In April and May, however, the marsh is alive with ducks and songbirds. And during the summer the refuge harbors large numbers of redhead ducks, yellow-headed blackbirds, and American coots. Altogether, at least 227 kinds of birds can be seen here, including bald eagles, egrets, hummingbirds, ospreys, peregrine falcons, sandhill cranes, and trumpeter swans.

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VISITOR INFORMATION

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www.fws.gov/midwest/horicon

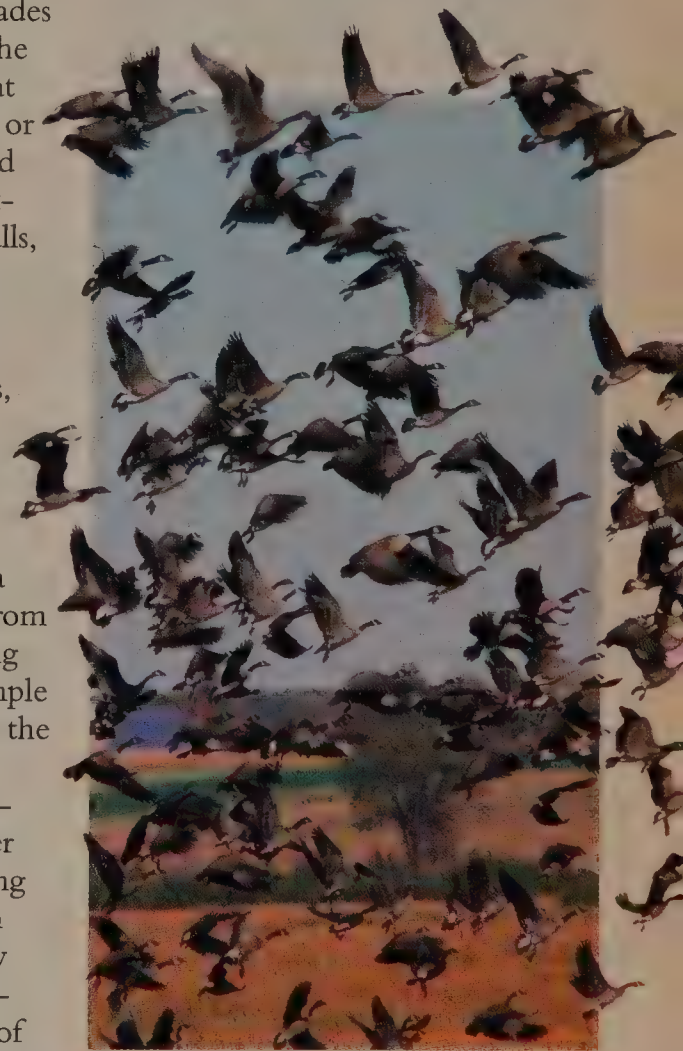
River, which temporarily changed the marsh back into a huge lake. But in 1869 the dam was removed, and the lake began to revert to marsh. The state wildlife area was

accompanied by common buckthorn, an invasive species from Europe. Common chokecherry and nannyberry are the most abundant smaller trees. The canopy provides shade for wildflowers including spring favorites

such as large white trillium, purple wake robin, both true and false Solomon's-seal, Virginia waterleaf, wild geranium, and species of yellow, white, and blue violets. Late goldenrod and panicked aster bloom in the autumn.

Upland woods Bitternut hickory, bur oak, red oak, shagbark hickory, slippery elm, and wild black cherry are the most prominent trees. Shrubs and small trees include black raspberry, cock-spur thorn, prickly ash,

prickly gooseberry, round-leaved dogwood, and wild black currant. Most of the wildflowers bloom during summer and autumn, including asters, Canada black snakeroot, goldenrods, tall agrimony, and white avens.



Canada geese at Horicon Marsh, a favored stopover during their fall migration



The Most Important Fish in the Sea: Menhaden and America
by H. Bruce Franklin,
Island Press; \$25.00

To my knowledge, I have never eaten a menhaden, though it is the most common fish native to the East Coast of North America. Nor is there a trace of menhaden in those fish-oil pills I down every morning (according to the label, they contain only anchovies, sardines, and soybeans). In fact, according to H. Bruce Franklin, a cultural historian at Rutgers University–Newark, menhaden rarely make it directly to anyone's table: their bodies are riddled with bones, their flesh is saturated with a disagreeable-tasting oil, and, even to hard-nosed fishermen, they smell awful. Yet, paradoxically, they are one of the most heavily harvested and critically important of all marine species.

As Franklin tells it, the commercial exploitation of menhaden began with the *Mayflower* landing in 1620. The Wampanoag Indians taught Puritan settlers that planting the seemingly useless fish along with seed corn would substantially increase the harvest. Or-

ganic fertilizer became increasingly essential as overfarming depleted New England soil, and within a century, farmers living near the coast were dumping menhaden by the thousands on each acre of their fields. Otherwise inedible, the menhaden had become an integral part of the American food chain.

By the middle of the 1800s, commercial menhaden fishing had become a growth industry. From Maine to North Carolina, huge rendering plants sprang up along the shore, grinding millions of bony carcasses into meal to spread across the wheat fields of an expanding nation. In the second half of the nineteenth century, menhaden factory ships began to take to the seas, scooping up vast schools of fish in mile-long nets. Menhaden ships could fill to capacity in a matter of days, reaping enormous profits for their owners.

Needless to say, the seemingly inexhaustible bounty did not last. It was about 1880 when the fishermen of Maine first began to notice the absence of menhaden, and the decline continues to this day. It was not immediately evident, however, that the species was in trouble. Improved harvesting methods, including the use of sonar, kept increasing the size of the menhaden catch. By the mid-1980s, 2.7 billion pounds of menhaden were caught each year, more than the combined catch of all other species of fish in the U.S. in both weight and numbers.

Today, of the fifteen states along the Atlantic coast, only Virginia and North Carolina permit industrial menhaden fishing. The industry has shrunk to one major company, Omega Protein, which maintains fleets in the Chesapeake Bay and the Gulf of Mexico. Its products are no longer major sources of raw materials for farming and manufacturing, but have dwindled to omega-3 supplements and feed for factory-farmed salmon.

Yet even one such company is too many, Franklin argues. As filter feeders that eat enormous amounts of microscopic plant life, menhaden underpin

the food chain, preventing algal blooms in bays and harbors and providing food for the bluefish, stripers, and other edible fishes that grace the table. Their absence is sorely felt wherever industrial interests have harvested them.

Franklin's book is thus not merely an elegant and erudite study of a moribund industry, but an impassioned plea to return our ailing East Coast waters to a state of healthy equilibrium.

Glorified Dinosaurs: The Origin and Early Evolution of Birds
by Luis M. Chiappe,
Wiley-Liss; \$69.95

In 1861, two years after the publication of Darwin's *Origin of Species*, a Bavarian quarry worker unearthed a nearly complete impression of a crow-size, winged reptile with feathers, sandwiched inside a 150-million-year-old slab of limestone. Named *Archaeopteryx lithographica* by the German paleontologist Hermann von Meyer, the striking fossil deepened an existing suspicion that dinosaurs akin to *T. rex* were the ancestors of modern birds.

Yet the kinship of *Archaeopteryx* to penguins, chickens, and the other 10,000 living avian species remained uncertain, primarily because the fossil record was slow to reveal further birdlike specimens. In succeeding years, facing the absence of evidence, paleontologists began to waver. Birds, perhaps, descended from an earlier, less specialized ancestor. Throughout much of the twentieth century, cautious paleontologists regarded the similarities between *Archaeopteryx* and avians as examples of convergent evolution, the independent development of similar structures in divergent species. That's the story of bird evolution I learned in school.

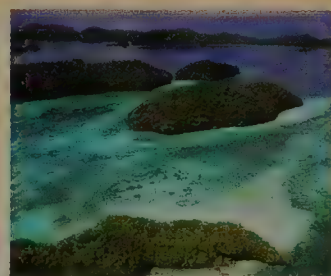
But in the past fifteen years discoveries of many fossils of feathered and winged dinosaur species, primarily from Asia, have made it clear that first impressions were correct. The family tree of birds has by now been so thoroughly sketched in, all the way

back to *Archaeopteryx*, that to Luis M. Chiappe, director of the Dinosaur Institute at the Natural History Museum of Los Angeles County and a specialist in avian paleontology, birds are not only descendants of dinosaurs, they are dinosaurs. In this handsome book, whose brilliant illustrations and magisterial breadth beg comparison with Bert Hölldobler and Edward O. Wilson's classic monograph, *The Ants*, Chiappe lays out the evidence and presents the case with a flourish.

Among the most impressive specimens he showcases is *Microraptor gui*, a broad-winged dinosaur about the size of a pheasant, whose fossilized remains were discovered in northeastern China in 2003. Like *Archaeopteryx*, it sported a long, plumed tail, and its wing feathers resembled the ones of modern birds, both in size and distribution. Possibly *Microraptor* could fly, but paleontologists remain puzzled by



Archaeopteryx lithographica



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a long row of feathers that stuck outward from its lower legs: in Chiappe's words, "a sort of avian version of the heel-winged Mercury of the Roman pantheon." Leg feathers might have added some lift if they could be held horizontally, but the anatomical evidence suggests that *M. gui* could not rotate its hind limbs that way.

The case of *Microaptor* highlights the difficulties paleontologists face in recreating the prehistory of birds. Color photographs throughout the book clearly convey the detail of skeletons and the astonishing filigree the plumage has etched into rock. But the artful visualizations of "living" creatures that accompany the photographs are at best educated guesses. The specifics of how early birds learned to fly (and how some later lost the knack), how they reared their young, how they hunted, and how long they lived, remain elusive.

And what is one to make of *Mononykus*, a species of graceful feathered creature discovered in the Gobi desert in the 1990s? Undoubtedly, it is part of the bird clan, but its stubby arms, each with a single claw, were plainly useless for flight. Did it perhaps burrow in the ground, rooting for grubs like an avian anteater? The question is just one of the many mysteries and delights of a book that dinosaur lovers and bird fanciers alike will want to make part of their permanent collections.

*Riddled With Life:
Friendly Worms, Ladybug Sex,
and the Parasites that Make Us
Who We Are*
by Marlene Zuk,
Harcourt, Inc.; \$25.00

Think of this book," its author writes, "as a disease appreciation course." Don't get her wrong, though: Marlene Zuk, an evolutionary biologist at the University of California, Riverside, is not suggesting that people learn to love tapeworms, papilloma viruses, or plague bacilli. Nor is she preaching that suffering from the depredations of such beasts is, somehow, a good thing for

body or spirit—at least, not always. Rather, she understands that invasive creatures are, like thunderstorms, earthquakes, and gravity, irreducible parts of the human environment. Living the good life, to Zuk, means reaching a kind of détente with the creatures that live around and in us.

That point of view may seem strange to those of us who live in cities where water is filtered and chlorinated, vaccination is nearly universal, and antibiotics are as common as table salt. But reflect on the cultural response in parts of Africa to the worms that cause schistosomiasis: the parasites are so much a part of everyday life that blood in a boy's urine is viewed as a sign of maturity, akin to menstruation. It's not that Zuk is advising third-world countries to shut up and learn to live with what they've got. Her insight into disease is that, though some invasive microorganisms should be controlled, others can be endured, and still others may actually be helpful.

The helpful ones, in fact, may form the majority. It's common knowledge that microorganisms thrive in the digestive tract, helping digest essential nutrients. But did you know that biologists estimate that microbial cells outnumber human cells in a person's body by ten to one? The body, like the democracy of ancient Athens, is an elite community of cells bearing human DNA, but supported by a vast underclass of foreign laborers. Eliminate that work force, and we're in trouble.

There are disturbing signs that the modern mania for antisepsis is already causing trouble. The appearance of antibiotic-resistant strains of bacteria is just one of those signs—a response to the man-made evolutionary pressure introduced by the overuse of wonder drugs such as penicillin. Epidemiologists have also noted a correlation between improvements in sanitation and the frequency of immune disorders such as asthma and Crohn's disease, an inflammatory disorder of the digestive system. Zuk even cites some intriguing

studies in which people were deliberately infested with a parasite to treat disease. For example, live eggs of the pig whipworm seem to send Crohn's disease into remission with no adverse side effects.

Zuk's book is not primarily about worms and germs, though. Those tiny stowaways are only examples of her greater theme: how parasitic species coevolve with their larger hosts. Viewed through the lens of Darwinian selection, parasites have influenced everything from dogs' penchant for rolling in garbage to the overwhelming preference of organisms for sexual rather than asexual reproduction. As the title suggests, we all may be riddled with life-forms that do not share our genes, but without them we would not be fully human.

LAURENCE A. MARSHALL, author of The Supernova Story, is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.

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Beep Beep

By Robert Anderson

Born in 1960, I have no memories of the heady years when our species first vaulted to a higher plane, Earth orbit—though I did witness the end of the space race, when astronauts landed on the Moon. What was it like, half a century ago, to tune a ham radio to *Sputnik 1*'s ominous beeping as the satellite sailed overhead? Still, I can get a taste of it: the evocative sounds are accessible on the Internet. And movies such as *October Sky* (1999) give me a sense of how the first artificial satellite drew young Americans into rocket science. Please visit the magazine online (www.naturalhistorymag.com), where I review Web sites devoted to *Sputnik*'s cultural and scientific impact.

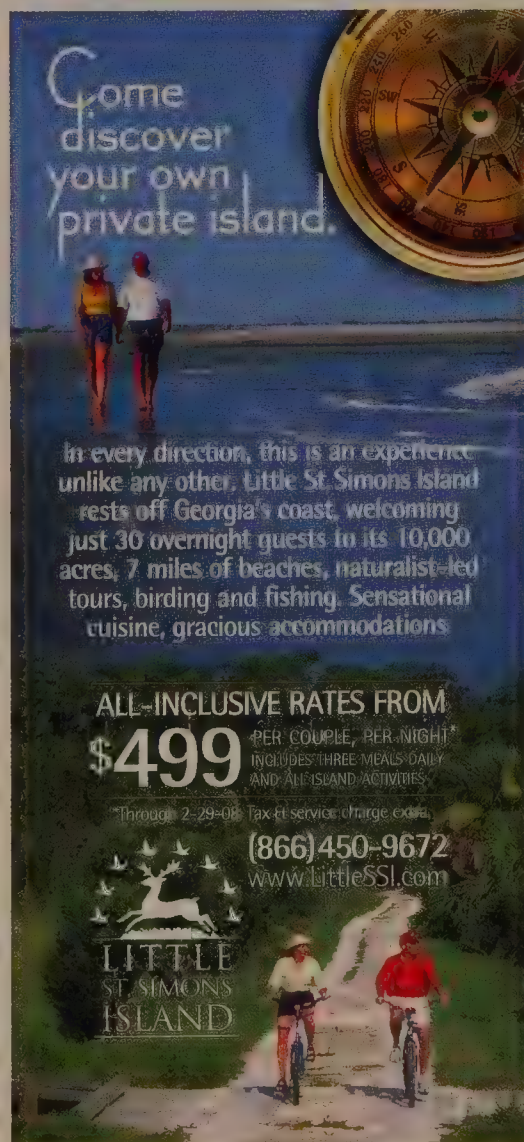
ROBERT ANDERSON is a freelance science writer living in Los Angeles.

Continued from page 27

customed and difficult stance on the ground simply for any of the commonly cited reasons. Only an arboreal ancestor that was already comfortable holding its body upright when moving around in the trees would have done so. When Alemseged finally liberates the Dikika child, perhaps its comparison with Lucy, an adult form, will provide new insight into the species' accommodations to life both in the trees and on the ground.

Meanwhile, Lucy's appearance in Houston is a landmark occasion, and she may well continue traveling to a series of international venues for five years or more. Most paleoanthropologists will be uneasy until she is safely "home." But as a roving ambassador, she not only reminds us of our remote human past, but also heralds dynamic new dimensions of Ethiopian achievement.

IAN TATTERSALL is a curator in the division of anthropology at the American Museum of Natural History in New York City.



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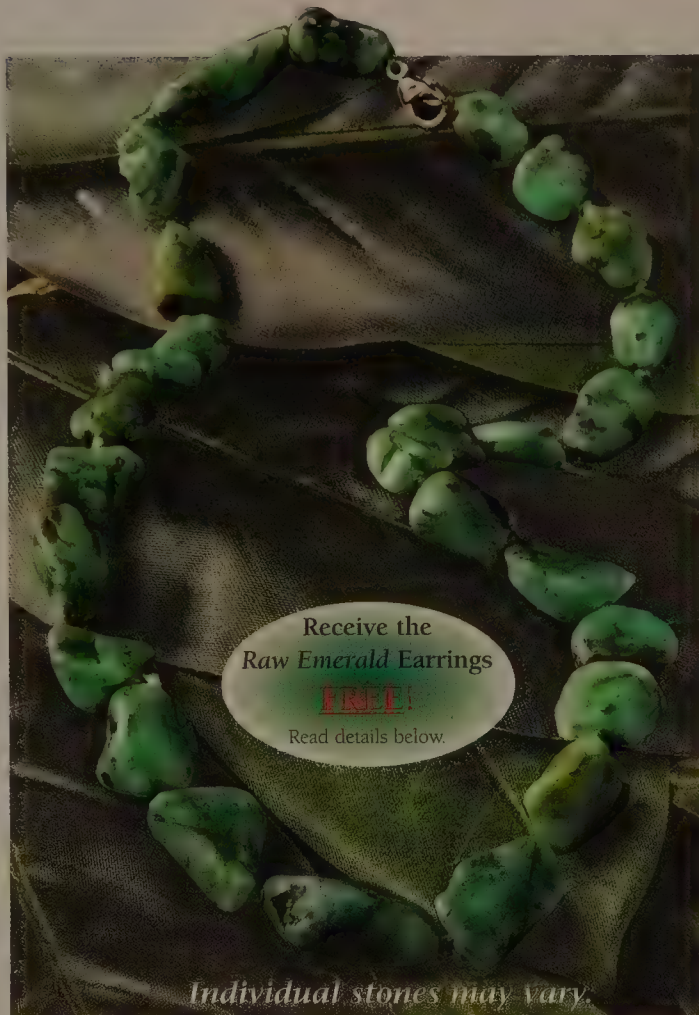
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Continued from page 25

its eighteen pounds of scientific instrumentation, into orbit.

If you want to reach orbital speeds (about 18,000 miles an hour), you'd better not burden your rocket with dead weight on the way up. Rocket motors are heavy, fuel tanks are heavy, fuel itself is heavy, and every kilogram of unnecessary mass schlepped into space wastes thousands of kilograms of fuel. The solution to dead weight is the multistage rocket. Use up the fuel in the first-stage fuel tank; throw it away. Use up the fuel in the next stage; throw that away too.

The rocket that launched *Explorer 1*—the Jupiter-C—was multistage. At takeoff, the loaded Jupiter-C weighed 64,000 pounds. The final stage weighed eighty.

Like the R-7 rocket that launched *Sputnik 1*, the Jupiter-C was a modified weapon. The science was a secondary, even tertiary, outgrowth of military R&D. Cold warriors wanted bigger and more lethal ballistic missiles, with nuclear warheads crammed into the nose cones.

High ground is the military's best friend, and what ground could be higher than a satellite orbiting no more than forty-five minutes away from a possible target? Thanks to *Sputnik 1* and its successors, the U.S.S.R. held that high ground until 1969, when, courtesy of von Braun and his colleagues, America's Saturn V rocket took the *Apollo 11* astronauts to the Moon.

Today, whether Americans know it or not, a new space race is under way. This time, America faces not only Russia but also China, the European Union, and India. Maybe this time the race will be one between fellow travelers rather than potential adversaries—more about fostering innovations in science and technology than about struggling to rule the high ground.

Astrophysicist NEIL DEGRASSE TYSON is the Frederick P. Rose Director of New York City's Hayden Planetarium at the American Museum of Natural History.

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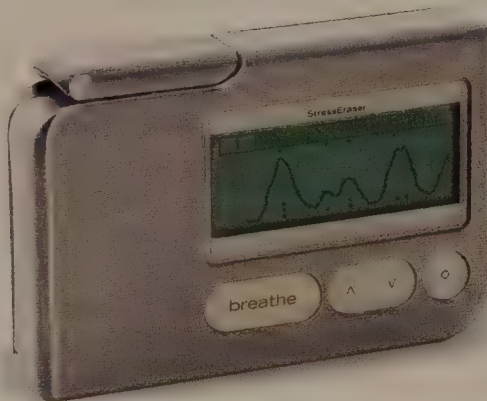
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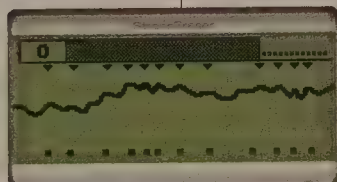
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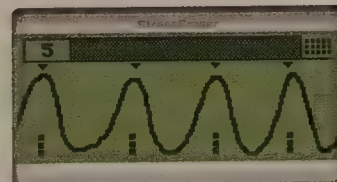
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John and AMANDA

A scientific legacy stretches from the core of the Sun to deep beneath Antarctic ice.

By Charles Liu

Just about everyone in the field of astronomy today has a story or two about John Norris Bahcall. Not all that long ago, at a small scientific conference, a fellow graduate student and I were chatting, when my friend suddenly gestured toward a tall, thin, bespectacled man who'd just come into view. "Is that John Bahcall?" he asked me. I told him it was. "Wow," he replied. "John Bahcall. He's got to be the most intimidating man in all of astronomy!" Considering that this friend is now himself one of the most accomplished—one might even say "intimidating"—astronomers of my generation, that was a weighty assessment indeed.

If there was anything intimidating about John Bahcall, though, it was the list of his achievements in astrophysics, not his demeanor. Although I only

interacted with him on a few occasions—conferences, colloquia, and the like—it was apparent to me that this quiet, intensely thoughtful man was a warm, kind soul who was deeply loved by his family and friends. When he died in August 2005 of a rare blood disorder, the entire astronomical community mourned his passing.

Bahcall's legacy extends into pretty much every corner of the study of the universe. Here's just a sampling of subjects to which he made major contributions: the standard model of the Milky Way galaxy; the standard model for the interior of the Sun; models of the distribution and behavior of dark matter; the characterization of galaxies that host quasars; the interpretation of absorption lines in the spectra of quasar light; the understanding of supermassive black holes; and the development and deployment of the Hubble Space Telescope.

His best-known work, however, was his contribution to the understanding of the elementary particles called neutrinos.

The study of neutrinos continues today around the world—even all the way "down under," in an intriguing project to which Bahcall contributed toward the end of his career. The project is known by its acronym, AMANDA,

the Antarctic Muon and Neutrino Detector Array, and it lies, for the most part, buried a mile down inside the ice at the South Pole.

Neutrino means "little neutral one" in Italian, the native language of the physicist Enrico Fermi, who coined the name in 1933. Three years earlier, the Austrian physicist Wolfgang Pauli had predicted the existence of the particle, to explain the puzzling observation that bits of energy seemed to be consistently missing from certain nuclear reactions. No one confirmed the existence of neutrinos, though, until 1956. The reason they went missing for so long is that they penetrate matter so effortlessly that they rarely leave a trace of their passage.

How penetrating are they? Here's an instructive example. Most physicists are accustomed to thinking of gamma rays as powerful, highly penetrating radiation. Yet the gamma rays generated at the core of the Sun are so thoroughly blocked and scattered by the surrounding dense solar plasma that they routinely take more than 100,000 years to bounce their way to the surface and out into space. By contrast, neutrinos generated at the same place, by the same nuclear reactions, flash through the overlying Sun-stuff in less than three seconds!

About half a century ago, astrophysicists—Bahcall among them—realized that neutrinos could be a key to learning just what is going on at the center of the Sun. Almost everything known about the universe comes from the study of light. So it is with sunlight, which takes only about eight minutes to reach us from the Sun's surface. Yet that light is actually quite ancient, the cumulative outcome of nuclear reactions that extend back long before early humans began painting on cave walls. Neutrinos, however, reach us fresh from the Sun's nuclear oven. Hence, Bahcall and his colleagues reasoned,

Globular modules that contain detectors for catching the rare signal of a passing neutrino are strung together vertically and buried deep within the ice at the South Pole. The artist's rendering across these two pages depicts some of the 680 modules in the current array.



neutrinos could reveal what's going on inside the Sun right now.

In 1964 Bahcall and the late physical chemist Raymond Davis Jr. proposed that a radically new kind of astronomical instrument could be built to study the Sun. Bahcall calculated that some 300 billion solar neutrinos should be passing through every square inch of Earth's surface each second. With that many incoming neutrinos, and enough matter to act as atomic targets, the neutrinos could be monitored despite the extreme rarity of their interactions.

Davis, for his part, described how to monitor the neutrinos: some of them could be detected as they streamed into a big tank filled with thousands of gallons of pure liquid, placed deep underground to shelter it from other forms of radiation. That idea led directly to the Homestake Gold Mine experiment in South Dakota—the world's first solar neutrino telescope. In the decades that followed, Bahcall, Davis, the Japanese physicist Masatoshi Koshiha, and many other investigators pursued the ghostly particles with a variety of such neutrino telescopes, but all based on Bahcall's and Davis's original ideas.

Serendipitously, in 1987, neutrinos reached Earth from an exploding star 170,000 light-years away. Worldwide, such neutrino telescopes collected only a few dozen neutrinos from Supernova 1987A, but that was enough to whet observers' appetites. We astronomers dreamt of creating neutrino telescopes that could detect neutrinos from other distant events and objects: quasars, supernovas, colliding black holes, and more.

Bahcall was as interested in those distant, typically extragalactic neutrinos as he was in the solar ones. Working with Eli Waxman, who at the time was one of his colleagues at the Institute for Advanced Study in Princeton, Bahcall calculated how many neutrinos should reach Earth from such faraway sources, and what kinds they would be. About that same time, he got involved with AMANDA.

As hard as it is for people to live and work at the South Pole, it's probably the best place on Earth to do neutrino astronomy. When neutrinos do have one of their rare interactions with matter, the interaction gives rise to a brief, weak flash of light called Cerenkov radiation. Under the right conditions, ice is transparent to Cerenkov light; so if such flashes are generated within ice, they can be detected. And one thing abundant at the South Pole is ice.

AMANDA is an array of light detectors buried in holes in the ice a few feet wide and more than a mile deep. Each hole is bored with high-powered drills that cut with superheated water instead of diamond bits. Before the water refreezes, long chains of basketball-size glass globes are lowered into the lower half of the holes [see illustrations on these two pages]. Inside each globe is a sensitive light detector, which monitors the ice in all directions. Operational for about a decade now, the array has been continually upgraded and expanded. The current configuration, called AMANDA-II, includes nineteen detector chains strung with a total of 680 globular modules.

The most recent studies have included a search for neutrinos from gamma-ray bursts, among the most powerful sources of energy in the universe. Those distant cosmic events release more energy in a few seconds than our Sun will generate in its entire 10-billion-year lifetime. The detection of neutrinos would provide clues to the still-mysterious process that generates the bursts.

The news so far is . . . no news. In a recent paper, AMANDA investigators reported no evidence of neutrinos from gamma-ray bursts. But the good news is, they didn't expect any. According to the Waxman-Bahcall predictions, AMANDA-II is not likely to see anything from gamma-ray bursts unless it can be made at least ten times more sensitive to neutrinos. And that's precisely what the South Pole experimenters are working to do. AMANDA-II is being incorporated

into a vastly expanded array, known as IceCube, which will have more than 4,000 detector modules spread through more than a cubic kilometer of ice. If the enlarged array detects neutrinos emitted from gamma-ray bursts, the achievement will become yet another parcel of John Bahcall's scientific legacy.

That reminds me of another incident from my grad school days. A number of us students were having lunch at an observatory cafeteria, discussing the giants of astronomy and astrophysics: Galileo, Newton, Hubble, and others. Who among our professors and mentors, we wondered, might be remembered in history alongside those immortal names? Even as we agreed that only time would tell, one of my classmates—she's now one of the world's leading astronomers—said, "Maybe John Bahcall?" His was the only name anyone mentioned.

CHARLES LIU is a professor of astrophysics at the City University of New York and an associate with the American Museum of Natural History.



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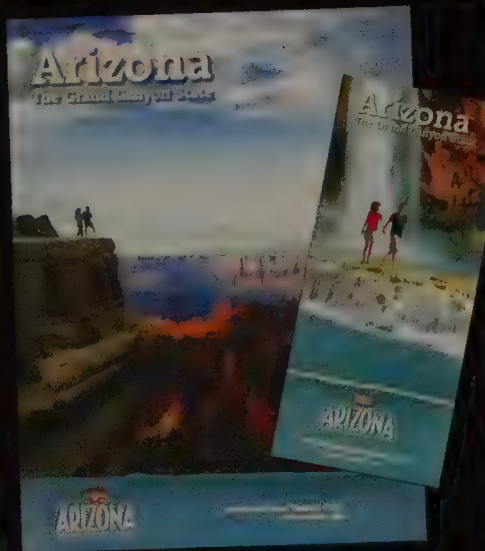


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THE SKY IN OCTOBER

By Joe Rao

Mercury begins October just past its greatest elongation, twenty-six degrees east of the Sun. But as seen from latitude forty degrees north, the planet, shining at magnitude zero, sets only three-quarters of an hour after sundown. In the continental United States, Mercury is probably visible to the unaided eye only from the Gulf Coast states and the Southwest. It reaches inferior conjunction (between the Sun and Earth) on the 23rd, but just a week later, assiduous observers who scan the eastern horizon with binoculars about forty-five minutes before sunrise might catch their first morning glimpse of the planet. That same morning, the first-magnitude star Spica lies about three degrees to the lower right of Mercury. You can locate Spica by extending the curve of the Big Dipper's handle about thirty degrees across the sky to the bright star Arcturus, then continuing another thirty-five degrees.

Venus arrives at the pinnacle of its current morning apparition. All month it rises at or shortly before 3:30 A.M. local daylight time, its earliest rising time this year and next. That's a full two hours before the first sign of dawn as October begins, and two and a half hours by month's end. During the first half of the month, an ever-changing celestial array greets early risers, as Venus, Saturn, a lovely crescent Moon, and the first-magnitude star Regulus square-dance across the eastern horizon. On the morning of the 7th Venus, Saturn, and Regulus form a large triangle around the Moon. On the 8th and 9th Venus appears to pass south of Regulus. Finally, on the 14th Venus passes south of Saturn. Venus reaches its greatest elongation, forty-six degrees west of the Sun, on the 28th. At the start of the month a telescope or a steadily held pair of binoculars reveals Venus as a wide crescent. But as the planet pulls ahead of Earth and speeds away in its orbit, Venus shrinks in diameter even as it grows fuller in phase. Its dichotomy, or half-full phase,

probably won't appear in telescopes until around the 3rd, nearly a week after one would expect it, at elongation. That mysterious lag is known as Schroter's effect.

Mars spends the month in the constellation Gemini, the twins—more precisely, within the feet and legs of the younger twin, Castor (according to old allegorical drawings of that constellation). The Red Planet rises well north of east around 11 P.M. local daylight time on the 1st, and closer to 9:30 P.M. by month's end. You'll find Mars poised near the meridian before the break of dawn.

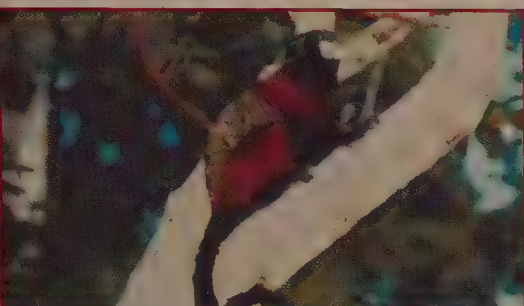
Jupiter, at magnitude -2.0 , is in the southwestern sky at dusk. It sets around 10 P.M. local daylight time on the 1st and almost two hours earlier by Halloween. As dusk fades, watch as the ruddy star Antares comes into view, twinkling and blinking between six and ten degrees below the King of Planets.

Saturn, shining with a mellow yellow light at magnitude $+0.8$ in the constellation Leo, the lion, rises around 4 A.M. local daylight time on the 1st and around 2:15 A.M. LDT by month's end. The ring system is gradually closing as seen from our earthly perspective, diminishing its inclination from 8.8 degrees to 7.4 degrees in the course of the month.

The **Moon** arrives at last quarter on the 3rd at 6:06 A.M. and wanes to new on the 11th at 1:01 A.M. It waxes to first quarter on the 19th at 4:33 A.M. and to full—the “Hunter's Moon of October” on the 26th at 12:52 A.M. Roughly seven hours later, at 8:00 A.M., the Moon reaches perigee, its closest orbital approach to the Earth, 221,676 miles away. As a consequence, the tides are far higher than normal during the following few days.

Unless otherwise noted, all times are eastern daylight time.

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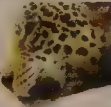


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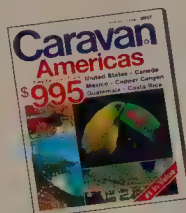
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Museum Events

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EXHIBITIONS

Mythic Creatures: Dragons, Unicorns, and Mermaids

Through January 6, 2008

Mythic Creatures traces the origins of legendary beings of land, sea, and air. Cultural artifacts bring to light surprising similarities—and differences—in the ways peoples around the world have depicted these beings, and fossil specimens suggest a physical basis for the many forms they have taken.

Mythic Creatures: Dragons, Unicorns, and Mermaids is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with The Field Museum, Chicago; Canadian Museum of Civilization, Gatineau; Australian National Maritime Museum, Sydney; and Fernbank Museum of Natural History, Atlanta.

Mythic Creatures is proudly supported by MetLife Foundation.



This extinct primate, *Giganthropithecus blacki*, may have inspired the myth of ape-men like the Yeti.

Undersea Oasis: Coral Reef Communities

Through January 13, 2008

Brilliant color photographs capture the dazzling invertebrate life that flourishes on coral reefs.

Beyond

Through April 6, 2008

Exquisite images from

unmanned space probes take visitors on a journey through the alien and varied terrain of our planetary neighbors.

The presentation of both *Undersea Oasis* and *Beyond* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Unknown Audubons: Mammals of North America

Through January 6, 2008

The stately Audubon Gallery showcases gorgeously detailed depictions of North American mammals by John James Audubon, best known for his bird paintings.

Major funding for this exhibition has been provided by the Lila Wallace-Reader's Digest Endowment Fund.

Exoplanets and the Search for Life

Through March 2008

Two striking astronomical instruments demonstrate the need for extremely specialized tools in the search for planets around stars other than our own Sun.

This exhibit, part of the education and public outreach efforts of NASA's Navigator Program, was made possible through a grant from NASA's Michelson Science Center at the California Institute of Technology.

LECTURES

The Unnatural History of the Sea

Tuesday, 10/2, 7:00 p.m.

Author Callum Roberts explores the history of commercial fishing and the depletion of marine life. He also suggests ways to restore the prosperity of the seas.

The Immortalists

Thursday, 10/11, 7:00 p.m.

Writer and reporter David M. Friedman tells the story

of aviator Charles Lindbergh and Nobel Prize-winning surgeon Alexis Carrel and their successful quest to build a machine to keep organs alive outside the body.

Leviathan: The History of Whaling in America

Tuesday, 10/30, 7:00 p.m.

Marine writer Eric Jay Dolin chronicles the social and economic history of the whaling industry in America, as well as the natural history of whales themselves.

SCIENCE AND SOCIETY

An Evening with Steven Pinker

Thursday, 10/4, 6:30 p.m.

See previous page.

An Evening with Oliver Sacks

Thursday, 10/25, 7:00 p.m.

See previous page.

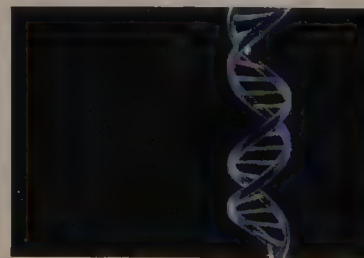
WORKSHOPS

Understanding Our DNA

Three Tuesdays, 10/9–23,

6:30 p.m.

Participants in this hands-on workshop will make their own DNA “fingerprints” and explore their implications.



Illuminated Manuscripts

Sunday, 10/14, 11:30 a.m.–

1:00 p.m. (Ages 5–7, each child

with one adult) and 2:00–

3:30 p.m. (Ages 8–10)

Thursday, 10/18, 6:30–

8:30 p.m. (Adults)

Grinding natural pigments and using real 22-karat gold leaf, participants will create their own medieval-style painting.

FAMILY AND CHILDREN'S PROGRAMS

Field Trip to the Moon

Every Wednesday, 10:30 a.m.

Guided by a live presenter, this new program flies visitors to the Moon in the Hayden Planetarium.

Wild, Wild World: Bats

Saturday, 10/27, 12:00 noon–1:00 p.m. and 2:00–3:00 p.m.

Not only are bats not to be feared, they need our protection. Find out more in this live-animal presentation.

Dr. Nebula's Laboratory: Mythic Stories and Tales

Sunday, 10/21 2:00–3:00 p.m.

(Families with children ages 4 and up).

Help Scooter, Dr. Nebula's apprentice, tell stories of magical creatures from the ancient past.



ROSE CENTER FOR EARTH AND SPACE

Sets at 6:00 and 7:30 p.m.

Friday, 10/5

Ray Mantilla and the Good Vibration Band

The 7:30 performance will be broadcast live on WBGO Jazz 88.3 FM.

Astrofavorites: The Earth and Space Collection

Three Thursdays, 10/4–18,
4:00–5:30 p.m. (Ages 4–6, each
child with one adult)

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**Twinkling Stars: Mythic
Creatures in the Sky**

Two Tuesdays, 10/9 and 16,
4:30–5:30 p.m. (Ages 4–6, each
child with one adult)

This introduction to the night
sky is for budding astronomers.

Visit the Space Station

Sunday, 10/28, 11:00–
12:30 p.m. (Ages 4–5, each child

with one adult) and 1:30–
3:00 p.m. (Ages 6–7, each
child with one adult)

Kids can “experience” life in
space in this workshop.

**Robots in Space II
(Intermediate)**

Three Wednesdays, 10/10–24,
4:00–5:30 p.m. (Ages 8–10)
Young robotics enthusiasts
can design robotic explorers.

**HAYDEN PLANETARIUM
PROGRAMS**

Dark Energy

Monday, 10/15, 7:30 p.m.
With Adam Riess of Johns
Hopkins University.

TUESDAYS IN THE DOME

Virtual Universe

Solar System Armada
Tuesday, 10/2, 6:30–7:30 p.m.

Celestial Highlights

Those Blinking Autumn Stars

Tuesday, 10/30, 6:30–7:30 p.m.

Public programs are made possible, in
part, by the Rita and Frits Markus Fund
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**HAYDEN PLANETARIUM
SHOWS**

Cosmic Collisions

Journey into deep space
to explore the hypersonic
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Narrated by Robert Redford.

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Japan; and the Shanghai Science and
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Made possible through the generous
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Cosmic Collisions was created by the
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Sonic Vision

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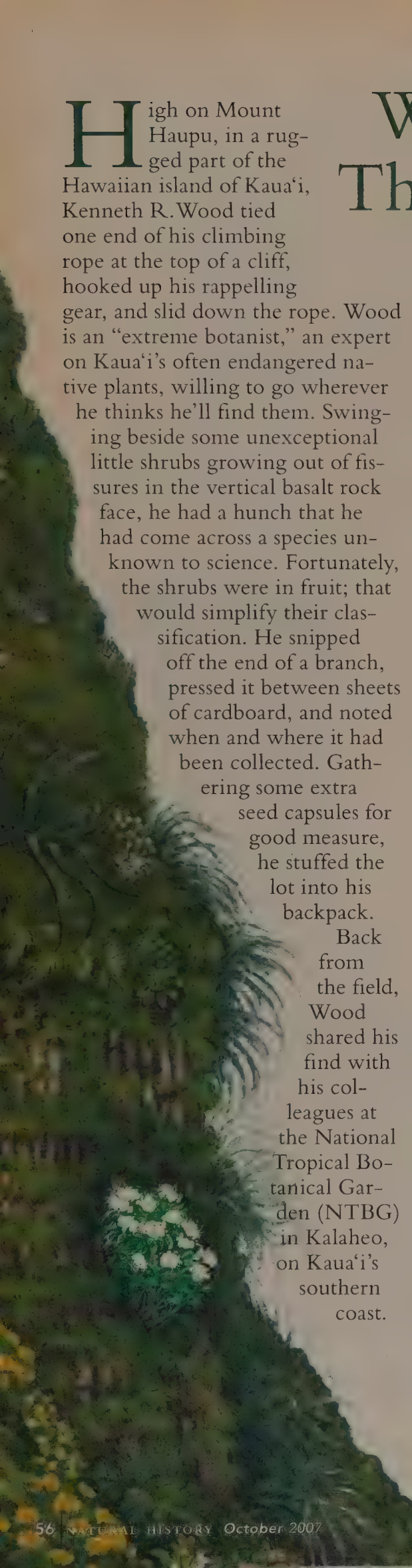
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Where Have All The Flowers Gone?

By Peter Brown



High on Mount Hapu, in a rugged part of the Hawaiian island of Kaua'i, Kenneth R. Wood tied one end of his climbing rope at the top of a cliff, hooked up his rappelling gear, and slid down the rope. Wood is an "extreme botanist," an expert on Kaua'i's often endangered native plants, willing to go wherever he thinks he'll find them. Swinging beside some unexceptional little shrubs growing out of fissures in the vertical basalt rock face, he had a hunch that he had come across a species unknown to science. Fortunately, the shrubs were in fruit; that would simplify their classification. He snipped off the end of a branch, pressed it between sheets of cardboard, and noted when and where it had been collected. Gathering some extra seed capsules for good measure, he stuffed the lot into his backpack. Back from the field, Wood shared his find with his colleagues at the National Tropical Botanical Garden (NTBG) in Kalaheo, on Kaua'i's southern coast.

Sure enough, the plant was new to science—a species of star violet that taxonomists will soon designate *Kadua haupuensis*, in the coffee family. The green thumbs in the NTBG "intensive care unit" coaxed the seeds into sprouting and distributed some of the young plants to other gardens around the island.

A year went by before Wood returned to the cliff to collect more seeds and reassure himself that his small, wild patch of *K. haupuensis* was still growing safely. But when he rappelled to the site, the plants had vanished. Browsing goats, a non-native species, had probably eliminated what nature had taken hundreds of thousands of years to develop. Only Wood's serendipitous encounter, and his dedication to his role as a modern-day Noah, had saved *K. haupuensis* from extinction.

Why should anyone care? Surely one rare plant, gone from the face of the earth, can't be one of humanity's great concerns. Isn't scurrying around collecting samples of species for a botanical "ark" a quixotic enterprise? It's a fair question. Maybe the Hawaiian experience is the best way to answer it.

When seafaring Polynesians first landed on the islands between 1,000 and 2,000 years ago, they brought along small pigs and Polynesian rats in their dugout canoes: food in a pinch. Much later, in the late eighteenth century, the first Europeans on the islands introduced goats and a bigger breed of pig, and black rats and Norway rats came along for the ride. The goats thrived in the wild, where they destroyed cliffside native plants and set off rock slides. The Euro-

pean pigs interbred with their smaller Polynesian cousins to create a rugged, intelligent, and ecologically destructive feral pig. And the three species of rats not only ate seeds of native plants,

but also raided birds' nests for their eggs. Afflicted as well by introduced avian malaria, the forest bird populations crashed. Plants dependent on forest birds for pollination were rapidly deprived of their services. In short order, a few invasive species had stumbled upon choke points of the entire ecosystem. Botanists at NTBG are rushing to save what's left of the native plants, but roughly a hundred Hawaiian taxa have already gone extinct.

Where are the choke points of other ecosystems? Can introducing a few species elsewhere cause the rest of the edifice to collapse? No one really knows. Nature can be highly resilient, but the Hawaiian experience shows that innocent mistakes can also lead to devastating changes on timescales measured not in millennia, but in years or months.

Sometimes you'll go out to an area and go all the way down a rope, and there's no plant," says Steven P. Perlman, another extreme botanist with NTBG. "Everything is dead. And at that point, you hit this low. I've even said I think we need hospice training, because we're dealing with terminal patients, and they die on you. If you see them for ten or twenty years, they're your friends, and you know what they look like. Then you come back and they're dead and dried up. I've gone back and actually witnessed extinction at least a dozen times. And then I think, yeah, I'm not coming here again. I'll go out and get drunk or something, because I've just lost a friend."

PETER BROWN is Editor-in-Chief of Natural History.

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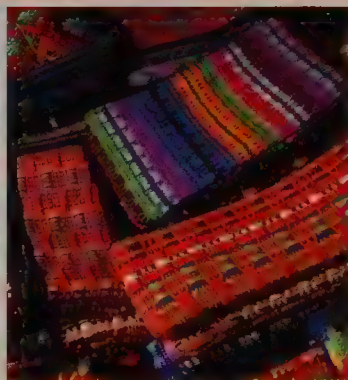
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ON THE COVER: A young boy drinks from a water tap in southern India. Photograph by Tim Gainey

Natural Resources



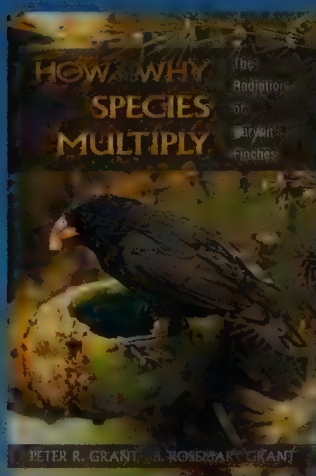
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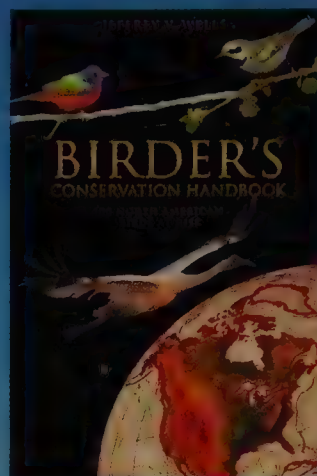
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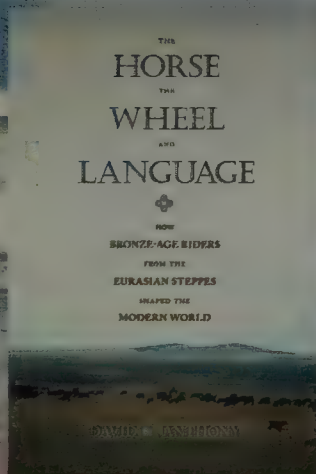
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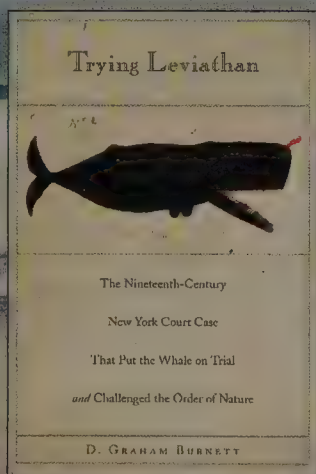
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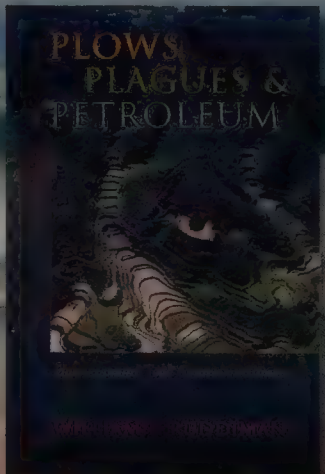
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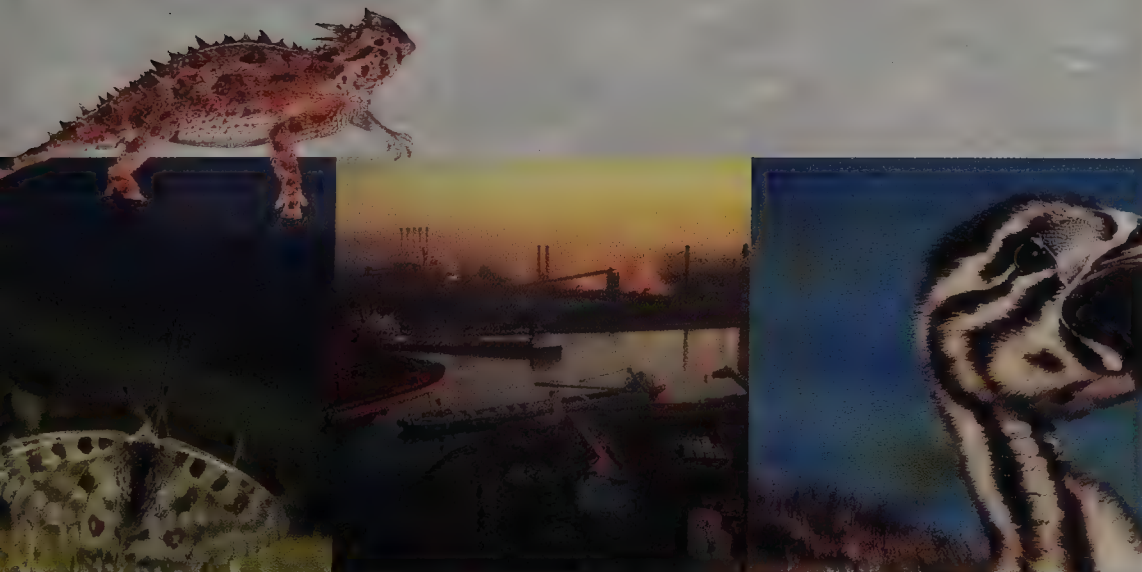
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THE NATURAL MOMENT

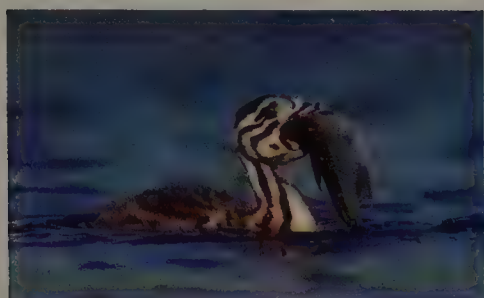
Eyes > Stomach

Photograph by Jasper Doest





◀ See preceding two pages



Too much of a good thing can be overwhelming—raw fish, supersize meals, even water. An overabundance of the latter has beleaguered the Netherlands for a millennium. The Dutch have struggled to control fifty-four rivers with dikes, levees, pumps, wind-mills, and more, all the while waging a never-ending battle with the North Sea. In the past fifty years the country has spent more than \$15 billion upgrading flood-control systems (which engineers in New Orleans are now studying).

Yet all that water is also one of the country's greatest resources—and among the many benefits, it attracts more than 350 species of birds. Photographer Jasper Doest spent two months near his home in Vlaardingen, in southwestern Holland, watching a mated pair of freshwater diving birds known as great crested grebes grow to a family of six.

Every morning and every evening Doest pulled on his waders before easing into a shallow canal to watch the grebes. He documented their courtship, nest building, egg laying, and, finally, their parenting of four zebra-striped chicks. Near the end of his stint, Doest caught the two-week-old chick pictured here mid-meal. The fish in its gullet, a bream served up by one of the parents, had been duly offered to the other chicks. But try as they might, none of them could swallow the wriggling fish—too much of a good thing for them to choke down. Finally one of the parents retrieved the catch and swallowed it in one gulp. —Erin Espelie

Seeking Fresh Waters

Maybe my questions are naive, “dumb,” or impertinent, but my job as a journalist is to ask them. How, I wonder, can the world be plagued with a worsening water crisis? After all, at least in the developed world, sophisticated water treatment brings sweet water out of the tap. And if water is treatable, doesn't that make it a fully renewable resource? So what's all the fuss about? I take up my questions with Eleanor J. Sterling, the director of the Center for Biodiversity and Conservation at the American Museum of Natural History in New York, who introduces this single-topic issue on freshwater resources (“Blue Planet Blues,” page 29); who writes, with Merry D. Camhi, about biodiversity in freshwater ecosystems (“Sold Down the River,” page 40); and who, not incidentally, is the curator of a new exhibition, “Water: H₂O = Life,” which opens at the American Museum on November 3.

As an educator and curator as well as an expert, Sterling understands where I'm coming from. “It's true,” she replies, “water doesn't disappear from the surface of the earth. But what we're doing to it is moving it from underground into surface- or ocean-water systems, and not replenishing it in the areas where it started. We're also moving it from one river basin into another, and in the process, moving organisms that may have a heavy impact on the new system.”

Does that mean there are freshwater ecosystems that should be set aside as natural areas? “I think there are,” she tells me, but it ought to be done on a case-by-case basis. “There's the Pantanal [a region of marshland in southwestern Brazil], the Congo River [in west-central Africa], the Okavango delta [in Botswana]”—areas that need to be maintained for their “incredible diversity of human populations as well as wildlife.” Other systems—the Florida Everglades come to mind—have already been badly damaged. “But the great thing about freshwater systems is that, while they're quick to react if we start to damage them, they are also often quick to revive.”

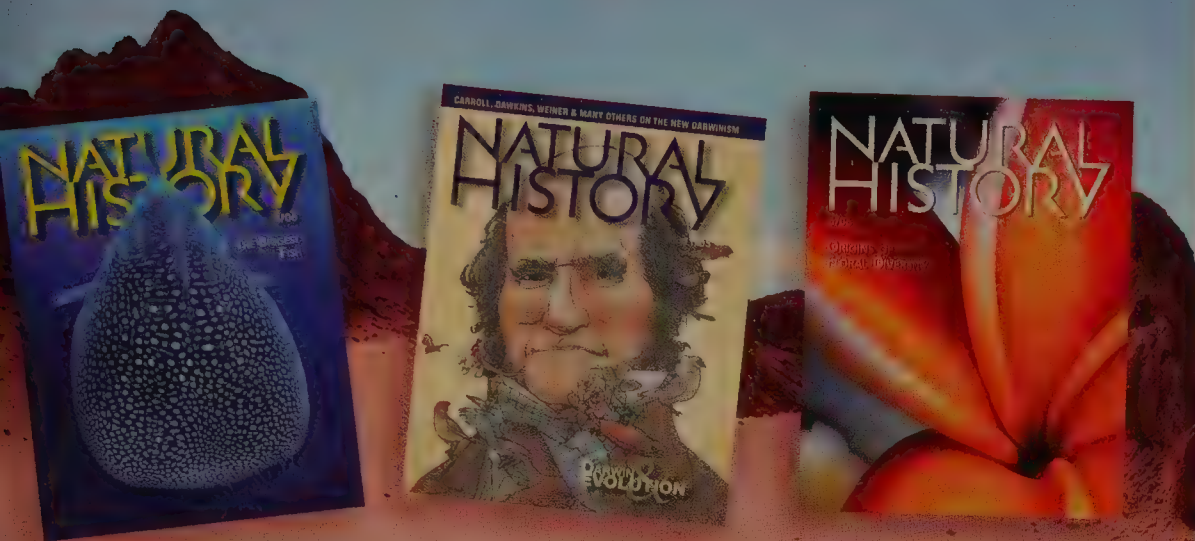
To listen to an audio recording of my interview with Sterling, go to our Web site (www.naturalhistorymag.com); you'll find the audio link on our home page.

• • •

Many times in the past five years as the editor of this magazine, I've enjoyed working with curators, writers, and scholars such as Sterling, who speak knowledgeably and passionately about their expertise. At times, I've envied the depth of their specialized knowledge. But I've also thrilled to the rich variety of topics that editing this magazine has continually given me license to sample.

Still, life is short, and I've concluded it's time to move on, to rebalance the trade-off between depth and survey that I've lived with for the past five years. Beginning with the next issue, my friend and colleague Vittorio Maestro will take over as editor of *Natural History*. Vittorio knows as much about this magazine as anyone else alive, having spent almost thirty years on the staff. He, too, has the magazine editor's fascination with variety, and he'll bring his own fresh perspective on the natural world that *Natural History* has covered for 107 years. I think you'll like what he brews up. —PETER BROWN

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CONTRIBUTORS

Wildlife photographer **JASPER DOEST** ("The Natural Moment," p. 6) often travels to foreign lands—Holland, Lapland, Poland—in search of interesting animal subjects. But for the baby grebe pictured in this issue, Doest stayed in his homeland, the Netherlands. See www.doest-photography.com to enjoy more of his images.

After twenty-five years of far-ranging fieldwork, **ELEANOR J. STERLING** ("Blue Planet Blues," p. 29 and "Sold Down the River," p. 40) knows the full spectrum of Earth's waterways well—a knowledge she amply poured, as curator, into the latest exhibit at the American Museum of Natural History, entitled "Water: H₂O = Life." Her expertise on one particular river, the Mekong, shaped her co-authorship of the book *Vietnam: A Natural History*. She currently directs the Center for Biodiversity and Conservation at AMNH and teaches at Columbia University in New York.

CHRISTOPHER J. MUNDY, **SHAWN M. KATHMANN**, & **GREGORY K. SCHENTER** ("A Special Brew," p. 32) study chemical physics at the Pacific Northwest National Laboratory in Richland, Washington. Although diverse in their respective areas of expertise, the trio shares a common bond: a fascination with the elusive nature of water. Mundy, who trained as a theoretical chemist, creates computer models of H₂O.



Top row, left to right: Doest, Sterling, Mundy, Kathmann
Middle row, left to right: Schenter, Camhi, Nappier, Lawrence
Bottom row, left to right: Schwab, Penland, Alwash, Postel

Kathmann, a physicist, developed a molecular theory for how water condenses, crystallizes, bubbles, and more. Schenter—also a physicist—has studied the chemical reactions of water on a quantum scale. Due to their collaborative efforts, water is less mysterious on the micro level.

Waters, according to **MERRY D. CAMHI** ("Sold Down the River" p. 40), have coursed through her entire life: from the chance meeting of her future husband on the mudflats of Shark River in New Jersey to her graduate work on sea turtles to editing *Sharks of the Open Ocean* (Wiley-Blackwell, 2008). She serves as the content coordinator of AMNH's exhibit on water.

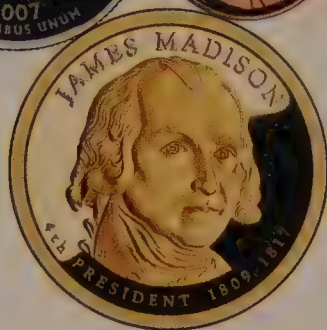
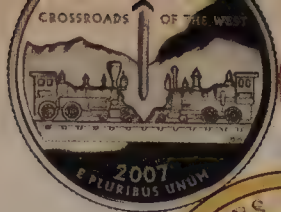
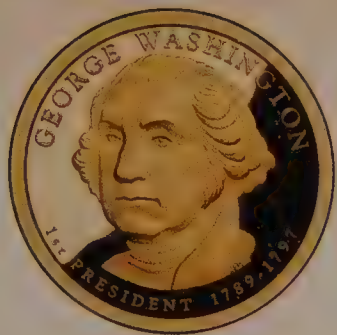
SHARON P. NAPIER, **ROBERT S. LAWRENCE**, & **KELLOGG J. SCHWAB** ("Dangerous Waters," p. 46) coordinated their efforts at the Johns Hopkins Bloomberg School of Public Health (JHBSPH) in Baltimore, Maryland in order to highlight some of the imminent dangers to the cleanliness of the world's dwindling freshwater supplies. Lawrence is the founding director of the Center for a Livable Future at JHBSPH. Schwab, director of the Center for Water and Health at JHBSPH, is currently trying to improve methods of detecting noroviruses. He and Nappier, a graduate student in his laboratory, are also studying those and other patho-

gens in non-native oyster species found throughout the Chesapeake Bay.

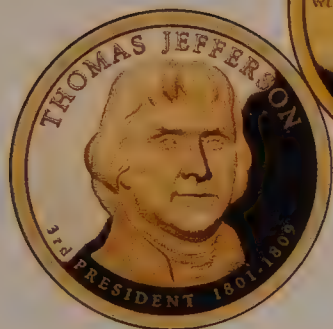
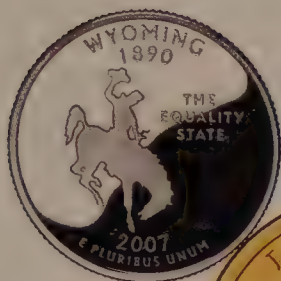
SHEA PENLAND ("When the Seas Come Marching In," p. 50) addresses the current state of affairs in the Mississippi Delta region and reconsiders the prophetic article he wrote for *Natural History* in February 2005. He is the Director of the Pontchartrain Institute for Environmental Sciences at the University of New Orleans, and the University's Braunstein Professor of Petroleum Geology.

As soon as Saddam Hussein was removed from power, **AZZAM ALWASH** ("Water at War," p. 56) quit his job as a geologic engineer in California and changed course: he set his sights on restoring the marshlands of Iraq. He continues to make headway on improving the wetlands' health with the Eden Again Project (www.edenagain.org).

SANDRA L. POSTEL ("Sharing the River Out of Eden," p. 60) examines the world through the lens of water—namely, how would the world look without it? Food security, environmental health, and international relations are a few of the touchstones Postel covers here and in her three books. She runs the Global Water Policy Project, geared toward sustaining the Connecticut River watershed, and directs the Center for the Environment at Mount Holyoke College in South Hadley, Massachusetts.



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LETTERS

The Deep Roots of Altruism

Joan E. Strassmann and David C. Queller's article "Altruism among Amoebas" [9/07] provides a fascinating account of the operation of altruism in both social amoebas and the human "dicty community." But I have a reservation: in paragraph two we are told that we should expect to find the roots of human altruism "deeper in nature"; in the penultimate paragraph, which returns to humans, we learn that human cooperation "often depends on reciprocation." Embedded within a discussion of specific genetic mechanisms, these statements may leave

the impression that the mechanisms described in the article apply to us to some degree. Although human altruism likely has a genetic basis, I am reasonably confident that the mechanism(s) does not involve the *dimA* or *csaA* genes. Because of this, *Dictyostelium discoideum* has no direct bearing on the "roots" of our own version of altruism. The research on amoebas supports the idea that altruism in humans has a genetic basis. However, the support is analogical, not functional.

James J. Moore
Department of Anthropology
University of California,
San Diego
La Jolla, California

DAVID C. QUELLER REPLIES: We agree that human altruism is unlikely to involve the same genes that we study in social amoebas. Indeed, many of those genes are absent from the human genome. We are trying to understand the general principles by which social genes evolve, principles that may eventually be shown to operate in humans. For example, it is likely that kin selection is involved in human altruism. We would be surprised if the insight from *dimA*—that social genes can reduce cheating by piggybacking on other essential functions—does not apply to other genes in other spe-

cies. The human genome might include so-called greenbeard genes—which enable altruism toward others who carry them—now that they have moved from hypothesis to reality, as in the case of *csaA*.

Dark Matters

I was intrigued by Donald Goldsmith's article "Dark Matter" [9/07], as I have been by all I have read on dark matter and dark energy. While I am not a physicist or a cosmologist, I can't help but wonder if there might not be yet another explanation for this extraordinary finding. We ask what there was before the big bang. Is it not possible that this non-



baryonic material was the medium in which the big bang occurred, and that it is a part of the fabric of a universe that preceded the one we know?

David Shander
Denver, Colorado

I wish that astronomical articles in *Natural History* paid less attention to exceptionally speculative issues like dark matter. By way of contrast to Donald Goldsmith's article, see "Modern Cosmology: Science or Folktale?" in the September/October issue of *American Scientist*. If anyone wonders why the American public is weary of funding these games, that article would

be a good place to begin looking for an answer. I suspect that there is a growing confusion in the scientific community about the ontological status of mathematics. Nothing in mathematics is real. There are often interesting and useful connections with the real world, but extending mathematical formalisms too far beyond experimental verification is simply abuse of a useful tool.

Dwight Brown
Kerrville, Texas

DONALD GOLDSMITH
REPLIES: I attempted to explain the chain of reasoning that leads most astrophysicists to conclude

that dark matter predominates over visible matter in the universe. Those astrophysicists recognize that their conclusion rests on certain assumptions and might be overturned, but current data suggest that dark matter is the most reasonable way to explain such matters as the observed motions of galaxies in galaxy clusters and the abundance of cosmic nuclei.

The question of what existed before the big bang remains largely unresolved, though the most widely accepted answer among cosmologists is that nothing existed, not even space or time. Dark energy deserves an article

by itself [see "Gravity in Reverse," by Neil deGrasse Tyson, 12/03–1/04]. As with dark matter, the conclusion that dark energy provides most of the energy in the universe seems well established, while remaining subject to disproof by further observations and better interpretation of the existing data.

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Animal Aqueduct

Cuddly they're not, but the Texas horned lizard and the Australian thorny devil share more than just prickles.

They boast the same remarkable adaptation to their arid homelands: scale-covered skin that captures water and carries it to the animal's mouth, enabling it to drink when raindrops hit its back or even, in the thorny devil's case, when its belly meets damp sand. Recently, a team led by Wade C. Sherbrooke of the American Museum of Natural History in New York figured out how this weird plumbing system works.

Using advanced microscopy, the investigators discovered minute ducts beneath the base of the skin scales. The hair-fine ducts connect to form a network that covers the lizard's body and opens up in the corner of the mouth. Sherbrooke and his colleagues think that water, pulled by capillary action, slips under the scales and spreads through the interconnected ducts. The animal, apparently by moving its tongue and jaws in a particular way, can draw the water into its mouth and take a sip.

As their names suggest, the Australian thorny devil and the Texas horned lizard live on opposite sides of the world and are not closely related, and so the water-transporting skin that cloaks both species is a striking example of convergent evolution.

(Zoomorphology)

—Stéphan Reeb

Texas horned lizard, top, and Australian thorny devil, right, are similarly plumbed.



A Grave Mistake

Dragonflies congregate at a cemetery in the Hungarian town of Kiskunhalas, perching on twigs and iron railings near polished black tombstones. It seems the insects mis-

take the horizontal surfaces of the stones for water, say Gábor Horváth of Eötvös University in Budapest and colleagues.

Still water usually reflects polarized light in a specific pattern, and some water-loving insects use the pattern to locate puddles and ponds. As Horváth's team discovered, reflections from horizontally oriented, polished black gravestones create the same pattern as water does. In several tests at the cemetery, the dragonflies—all members of the genus *Sympetrum*—showed no interest in matte dark objects or in polished light-colored stones, neither of which reflect polarized light in just the right way.

Dragonflies mate near water and lay their eggs in it. Horváth's team observed males and females at the cemetery flying in tandem over the black stones, sometimes touching them as if to deposit eggs. The researchers found no eggs on the graves, but the possibility remains that gravestones—and other dark, shiny horizontal surfaces where dragonflies sometimes gather, such as pools of oil and spiffy cars—can act as “ecological traps” for insects attracted to certain patterns of polarized light. (*Freshwater Biology*) —S.R.

Sympetrum dragonfly perches in a Hungarian cemetery.



When Life Gives You Lemmings

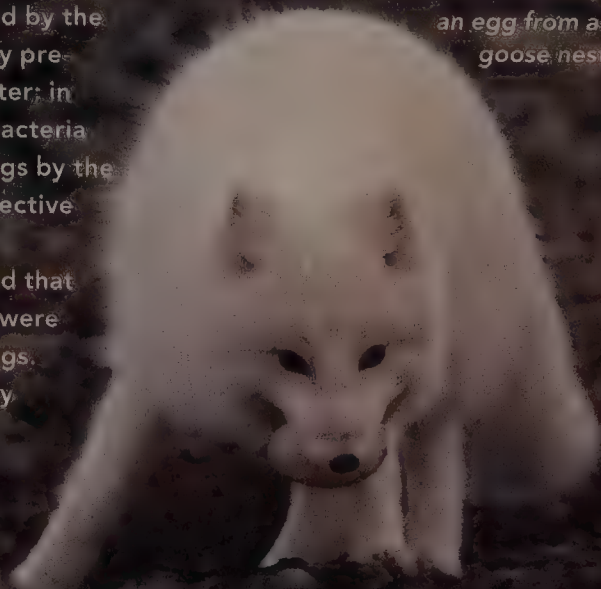
In a good summer, an Arctic fox living near a goose colony on the Canadian tundra can steal as many as 2,000 eggs. Foxes bury most of their loot for future consumption, and they don't bother to stamp an expiration date on it. A year later the eggs are still edible, a new study shows.

During four consecutive springs, just before snow geese arrived on the tundra to breed, Gustaf Samelius, then a graduate student, and three colleagues at the University of Saskatchewan in Saskatoon collected blood from wild foxes. By analyzing the proportions of the isotopes carbon-13 and nitrogen-15 in the blood samples, the team established that goose eggs were

an important part of the foxes' diet even eleven months after being cached by the carnivores. Freezing undoubtedly preserves the eggs through the winter; in the fall and spring, rot-causing bacteria seem to be inhibited in intact eggs by the shell and membrane and by protective proteins in the white.

The researchers also discovered that in years when collared lemmings were abundant, the foxes ate fewer eggs. Cached eggs, it seems, are merely a standby in case the foxes' preferred food—lemming—is in short supply. (*Journal of Animal Ecology*) —S.R.

Arctic fox snatches an egg from a goose nest.





Ancient bee, trapped in amber, bears a load of orchid pollen.



California ground squirrel confronts a rattlesnake by flagging its tail in warning.

One for the Record

When the poet William Cullen Bryant wrote that the “loveliest of lovely things are they on Earth that soonest pass away,” he could easily have been describing orchids. Although experts agree that they’ve brightened the planet for millions of years and now number well over 20,000 species, the ephemeral plants have never appeared in the fossil record . . . until now.

An ancient stingless bee was found trapped in a piece of amber 15 to 20 million years old, with a precious few packets of orchid pollen clamped to its back. That singular plant-and-pollinator duo enabled Santiago R. Ramirez, a graduate student at Harvard University, and several colleagues to make previously impossible determinations about orchid evolution.

On the basis of the shape and packaging of the pollen grains, Ramirez positioned the orchid—*Meliorchis caribea*, a species new to science—on a phylogenetic tree. He then calibrated the tree with existing molecular data from the rest of the orchid family. Orchids, he found, started diversifying about 65.5 million years ago, from a common ancestor that probably arose some 80 million years ago. That means the original lovelies may have bloomed alongside the dinosaurs—much earlier than most orchid biologists had thought. (*Nature*) —Erin Espelie

Tell Tail

Coping with rattlesnakes is a fact of life for California ground squirrels. Fortunately, adult squirrels are immune to the snake’s venom. To protect their susceptible pups, when a rattler comes near they sound an alarm, then fling pebbles and sand at the predator. Now, a team at the University of California, Davis has discovered a previously unknown means of communication in the squirrels’ defensive arsenal: they warm up their tails to tell the heat-sensitive vipers they mean business.

Biologists have long observed squirrels flagging their tails in the air when threatened by rattlesnakes or gopher snakes. By pointing an infrared camera at the squirrels, Aaron S. Rundus and his team discovered that the squirrels’ tails were several degrees hotter than normal while waving at rattlesnakes, which have specialized heat detectors, but not while waving at gopher snakes, which lack such detectors. The thermal signal, the authors posit, is meant for rattlesnakes.

To test whether rattlesnakes actually pay attention to the warning, Rundus’s team designed a robotic squirrel with a temperature-controlled tail. Indeed, when the tail warmed up, rattlesnakes slithered away, apparently discouraged to learn that the “squirrel” had spotted them, foiling a surprise attack. The squirrels’ use of heat to get their message across is a first in the animal kingdom. (*PNAS*)

—Brendan Borrell

Nothing Much

News flash: astronomers think they’ve discovered a whole lot of nothing. In the constellation Eridanus, near Orion, some 10 billion light-years from Earth, there appears to be a vast expanse of empty space, completely devoid of matter—no stars, no planets, no black holes, no gases, not even any dark matter. It’s almost a billion light-years across, more than sixty times larger than any previously known cosmic void.

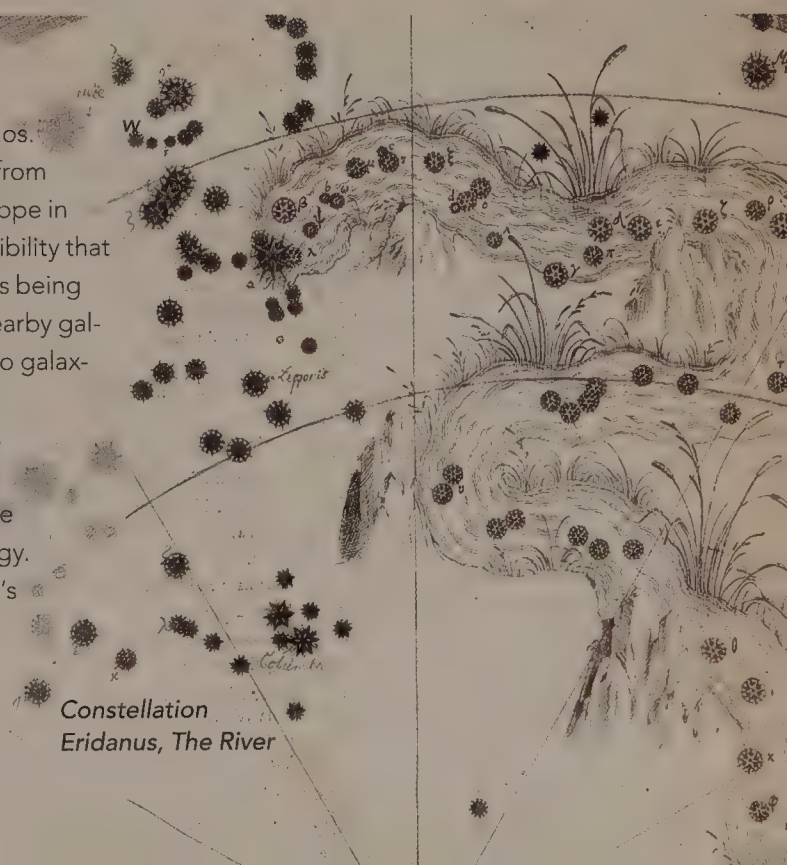
The void’s discoverers—Lawrence Rudnick of the University of Minnesota, his collaborator Liliya R. Williams, and his graduate student Shea Brown—already knew the region was unusual because cosmic microwave background radiation (ubiquitous faint radio waves left over from the big bang) appears much weaker

there than elsewhere in the cosmos.

Then the team’s analysis of data from the Very Large Array radio telescope in New Mexico eliminated the possibility that the region’s microwave signal was being obscured by radio waves from nearby galaxies: there are just too few “radio galaxies” in the vicinity to do the job.

The remaining possibility was empty space, which could also weaken the signal—thanks to the effect of omnipresent dark energy. Rudnick’s calculation of the void’s colossal size is based on the apparent weakness of the radiation. (*Astrophysical Journal*)

—S.R.



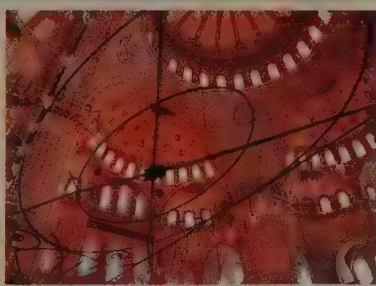
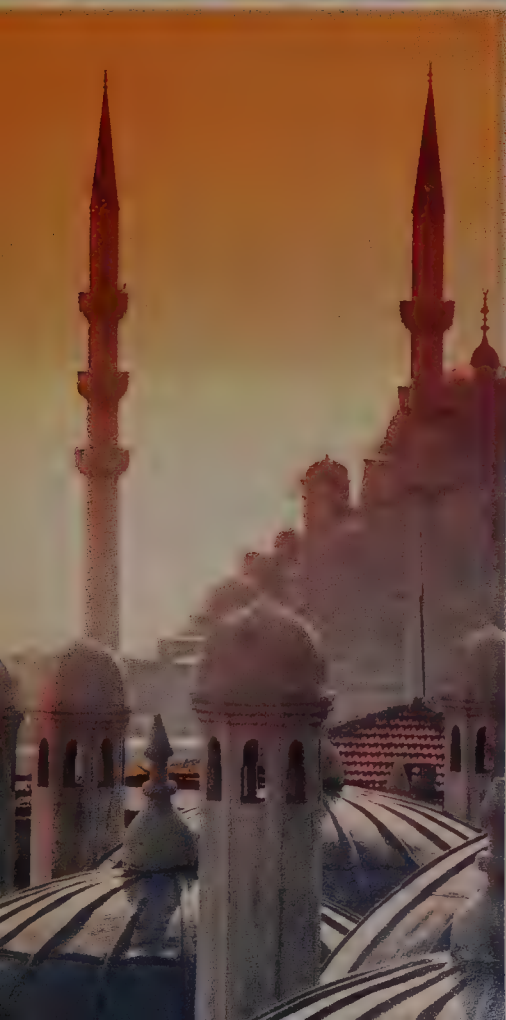
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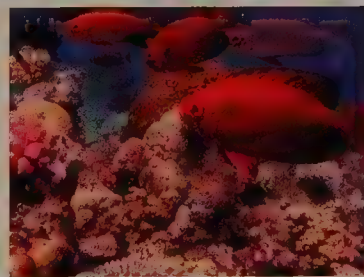
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Losing Contact

Agriculture, development, and logging are often blamed for habitat fragmentation. Now we can blame global warming, too. Worldwide, a combination of rising temperatures and fire suppression by foresters is causing mountain tree lines to climb. The trees are creeping into alpine meadows and carving them to pieces; along the way, animal populations are being carved up as well.

Take Jumpingpound Ridge in the Rocky Mountains of Alberta. There, trees now live some 650 feet higher up the mountainsides than they did forty years ago. Each year from 1995 through 2005, Jens Roland of the University of Alberta in Edmonton and Stephen F. Matter of the University of Cincinnati surveyed the number of Apollo butterflies, *Parnassius smintheus*, living in a series

of alpine meadows on the ridge. After counting each meadow's butterflies for eleven summers and comparing the fluctuations in their numbers, Roland and Matter discovered that the broader the swath of forest between two adjacent meadows, the less in synch were the ups and downs of the two butterfly populations. In other words, populations divided by thick forest fall out of touch and become increasingly independent.

The encroaching forests, the ecologists conclude, prevent the Apollos (and quite possibly other organisms) from dispersing and thus mixing their genes. That could be bad news for the butterflies and other locals: isolated populations are more vulnerable to being wiped out than are connected populations. (PNAS) —S.R.

Apollo butterfly
basks in a Rocky
Mountain meadow.



Bias or Balance?

Scientific consensus that humans have caused global warming coalesced in about 1995. Yet for the next decade many Americans still believed that humankind's role in the emerging crisis was a matter of great debate. A new study lays some of the blame for that national misconception on the nightly TV news shows. To avoid the appearance of bias, they continued to air contrarian viewpoints long after the scientific debate was settled.

Maxwell T. Boykoff of the University of Oxford analyzed 143 news segments about climate change that were broadcast between 1995 and 2004 on programs ranging from the CBS *Evening News* to CNN's *Wolf Blitzer Reports*. Only 28 percent of the segments paralleled scientific opinion in portraying humans as the main cause of global warming, Boykoff discovered. Just a handful of segments went so far as to suggest that humans had a negligible effect on Earth's climate, but a full 70 percent gave roughly equal play to both sides of the debate.

Journalistic skepticism is useful, but Boykoff thinks that in this case, overrepresentation of minority opinions amplified uncertainty in viewers' minds. Fortunately, he notes, the accuracy of TV news—at least regarding humanity's role in global warming—has improved since 2004. (*Climatic Change*)

—B.B.

Change on the Range

On rangelands around the world, grasses are giving way to woody shrubs. Deer and antelope still have room to play, but the encroaching shrubbery worries ranchers, who rely on grasses as forage for their cattle. As has long been suspected, the rising concentration of atmospheric carbon dioxide (CO₂) contributes to the proliferation of shrubs.

In a five-year experiment on Colorado's shortgrass steppe, Jack A. Morgan of the U.S. Department of Agriculture in Fort Collins, Colorado, and colleagues placed six clear-sided, open-topped enclosures on the ground before each growing season. Air circulated continuously through all six enclosures; three received natural air, and

three received air with double the current atmospheric concentration of CO₂.

Inside the enclosures with double-strength CO₂, fringed sage (*Artemisia frigida*)—a small shrub unpalatable to cattle—flourished dramatically, while almost all forage grasses grew at their normal rates. Like many other rangeland shrubs, fringed sage absorbs more atmospheric carbon during photosynthesis than most grasses do. Morgan's team expects that shrubs worldwide are responding to elevated CO₂ in a similar fashion. Since atmospheric CO₂ may well double by 2100, the explosion of shrubbery in the experimental enclosures could occur on many open rangelands, with inestimable economic and ecological consequences. (PNAS) —Harvey Leifert

Cattle ponder grass futures
on the Colorado range.





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Offering stunning views of Sedona's red rocks, **The Gallery on Oak Creek** emphasizes not only the taste of food but also its presentation. In addition to a new menu and redesigned interiors, this restaurant features original art in a variety of media from local as well as national artists—both on the tabletops and the walls. Guests are given an "art menu" detailing the artwork in addition to the menu of eclectic cuisine and fine wines.

The Hualapai Lodge, on the western rim of

the Grand Canyon, is a perfect base from which to embark on a range of activities, including whitewater rafting, helicopter tours, fishing, and hiking. In between, try the authentic Native American cuisine of **Diamond Creek Restaurant**, located at the Lodge. Specialties include the Hualapai taco and stew with Hualapai fry bread.

In Phoenix's Arcadia District, **Chelsea's Kitchen** showcases American-Southwest style cuisine and has earned praise from visitors as well as locals. Sit in the back patio, overlooking the Arizona Canal, and enjoy the casual atmosphere while sampling the local favorites of prime rib, roasted chicken, and green chile stew. With views of the spectacular Catalina Mountains, **Terra Cotta** is one of Tucson's most lauded





restaurants. Featuring innovative regional cuisine—a fusion of native Southwest and northern Mexican ingredients and contemporary French cooking—Terra Cotta is known for its complex and robust sauces. The atmosphere is relaxed, with an intimate outdoor area, and indigenous Southwest materials incorporated into the décor. Every twelve to eighteen months, Terra Cotta commissions a piece of artwork to

use in its Wine Label Artists' Series. The artwork is displayed at the restaurant and reproduced as labels for the house wine collection, menu covers, postcards, promotional pieces, and brochures. The series provides an opportunity to promote Southwestern art and local artists.

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ARIZONA
GRAND CANYON STATE

◆ Tucson ◆

Just an hour away from Mexico, Tucson has a long history of settlement by ancient tribal peoples, Spanish explorers, and Anglo frontiersmen.



People," visit the Tohono O'odham Nation Cultural Center & Museum, which opened in June of this year in Topawa, the capital of the Tohono O'odham Nation. This \$15.2 million state-of-the-art facility houses priceless artifacts, some dating back nearly 10,000 years. To showcase the Tohono O'odham's traditional life and history, the exhibits include ancient arrowheads, tools, and pottery as well as many works from the 1700s to the present, including modern paintings, photographs, baskets, and World War I memorabilia.

To learn more about Tucson's Spanish history, follow the Juan Bautista de Anza National Historic Trail, which

THIS MODERN TOWN WITH AN OLD West flavor is set amid spectacular beauty, surrounded by a forest of giant cacti, a lush, flowering desert, rugged canyons, and ringed by five unique mountain ranges.

The blending of cultures is evident throughout Tucson. You'll see it at the Mission San Xavier del Bac, an outstanding example of Spanish Mission architecture that is located on the Tohono O'odham Indian Reservation. The Mission was founded by the Jesuit priest Father Kino in 1700, but many say the design and construction of the church may have been the work of the Tohono O'odham; fittingly, you can admire the Mission, then step outside to sample some Indian fry bread, dipped in honey. The shining white church, which combines Moorish, Byzantine, and late Mexican Renaissance elements so seamlessly it's hard to tell where one begins or ends, was built between 1783 and 1797. The Tohono O'odham, whose ancestors welcomed Father Kino to their village, are descendants of the Hohokam Culture, an ancient people of the Southwest. To learn more about the "Desert

commemorates the route followed in 1775–76 by a Spanish commander who led a party of colonists on an expedition from Mexico to found a presidio and mission near the San Francisco Bay. The trail takes you to Tubac Presidio, now a state park, and to Tumacacori National Historical Park, where you'll see the abandoned ruins of three Spanish colonial missions, including Tumacacori itself, which dates back to 1691.



Go to visit Tucson.org/culture for more information.

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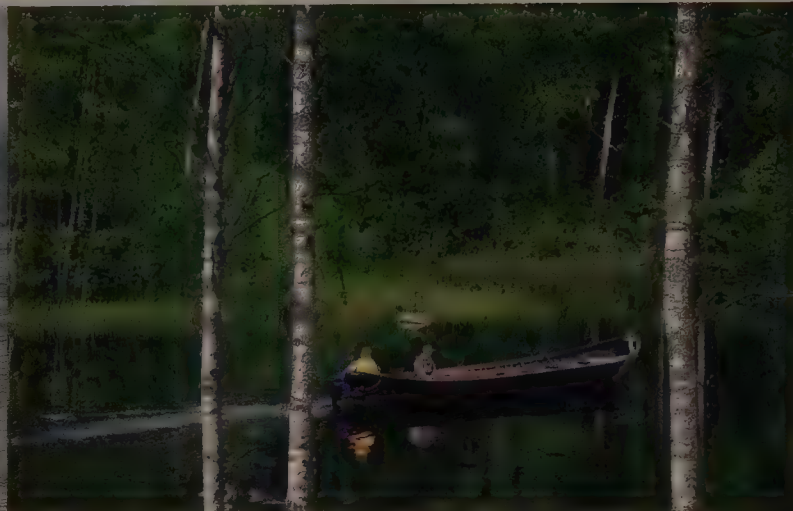


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◆ Finland ◆



Karsten Bidsrup

FINLAND IS KNOWN AS THE LAND OF A THOUSAND LAKES, BUT IT ACTUALLY HAS even more: 187, 888 at the last count. The lakes are linked by a labyrinth of rivers, straits, canals, and inland waterways, creating many opportunities for outdoor recreation. In summer the lakes are full of boaters and swimmers, and in winter they are a mecca for skaters and skiers.

Almost 40 percent of the eastern part of the country is covered with water and is known as the Lake District or Lakeland. On the border with Russia, the Saimaa lakes, interconnecting waterways dotted with lovely small towns, are a haven for vacationers drawn to their beauty and peaceful environment.



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This is the perfect place for booking a lakeside cottage or farm holiday, taking a cycling tour, or hiking in the Linnansaari and Kolovesi national parks. Finland enjoys some of the most unspoiled natural environment in Europe, and it is on display in these two parks. Linnansaari, with over 130 islands and many lakes, is a typical Finnish landscape. Kolovesi National Park conserves the ecosystems of the inland archipelago of the Saimaa lakes and forests. Both parks protect the habitat of the Saimaa ringed seal. The Turku Region, in southwest Finland, is where the recorded history of Finland begins. Turku is not only Finland's oldest city but also its first capital. The Turku archipelago, in the Baltic Sea, was created by the Ice Age and is characterized by rocky islets, forested islands, and open sea.

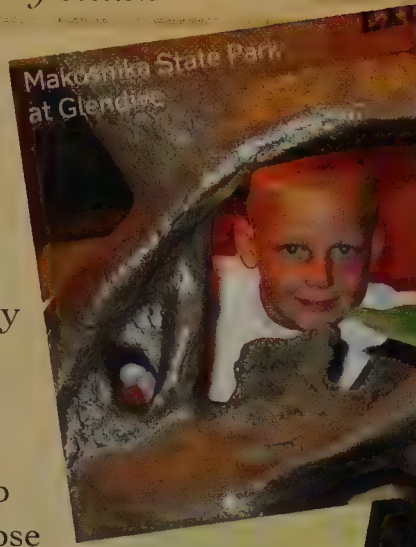
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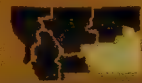


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Currituck County

NORTH CAROLINA



Photos: Currituck Outer Banks Travel & Tourism Department

CURRITUCK COUNTY, tucked in the northeastern corner of North Carolina, lies along the Outer Banks on a picturesque peninsula between Kitty Hawk and Chesapeake, Virginia. Bordered to the east by the Currituck Sound, the county is separated from the Atlantic Ocean by natural barrier islands and is known for its pristine beaches and historic attractions.

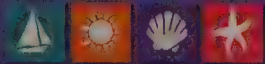
A visit to Currituck Heritage Park in Corolla transports you to life on the Outer Banks in the 1920s. Featured at the park is the Whalehead Club, originally an exclusive hunt club when built in 1925. The fully restored building is a popular attraction, along with a historically landmarked boathouse and footbridge. Nearby sits the Currituck Beach Lighthouse and light keeper's house. For over a century, the Lighthouse guided ships safely along the Chesapeake Bay to nearby ports. Climb to the top for spectacular water views and unforgettable sunsets.

The Outer Banks Center for Wildlife Education, also in the park, contains educational exhibits and conservation information. Currituck Sound is noted for its fish and waterfowl populations, as well as the migratory paths of ducks and Canada geese.

While in Currituck County, be sure to see the Corolla Wild Horses – Spanish mustangs that have roamed freely on the Currituck Outer Banks for 400 years.



Picture your vacation on the Currituck Outer Banks! Sweeping waterfront sunsets and unspoiled beaches are only the beginning of what you'll experience. For a look at our fascinating attractions and activities contact us for a free visitor's guide today.


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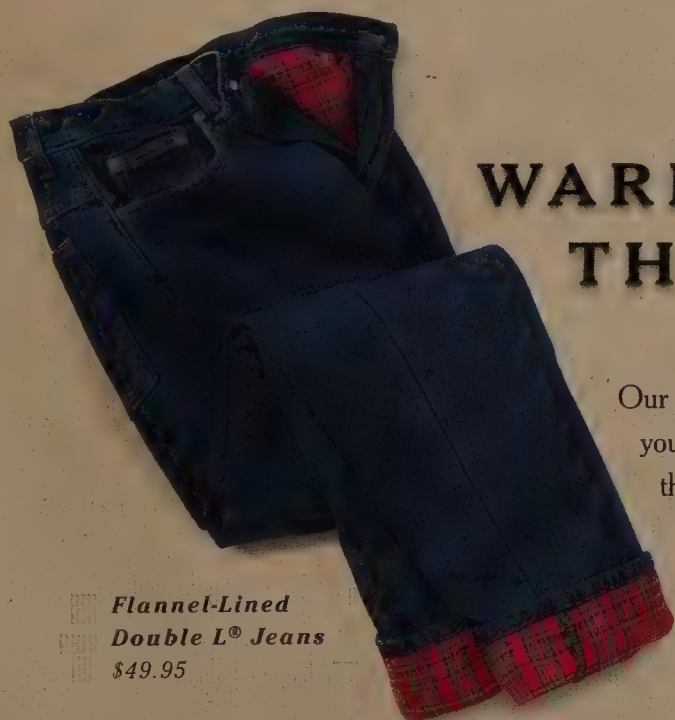
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water
the wellspring of life

A Special Report on the World's Freshwater

BLUE PLANET BLUES

*Demand for freshwater threatens to outstrip supply.
How can we meet the needs of all of Earth's species?*

By Eleanor J. Sterling

Water: evolving life-forms crawled out of it hundreds of millions of years ago, yet it still envelops us in our fetal state, suffuses every tissue of our body, and surrounds our drifting continents. From ancient origin myths and ritual baths, to Handel's *Water Music* and the play of ornate fountains, to water parks and water slides, we celebrate it. Water molecules move through the years and across the globe, from rivulets to rivers to oceans, rising into the atmosphere and falling back to land, connecting each of us to the rest of the world. In this global cycle, each of us is always downstream from someone else.

Despite all the water in the world, only a small fraction is available to us and other species that depend on freshwater. Salty seas account for more than 97 percent of the water on Earth. Of the remaining 3 percent or so, at least two-thirds is tied up in glaciers, ice caps,

and permafrost, or else lies deep underground, of little use to those of us living on the land above.

This special single-topic issue of *Natural History* examines that last 1 percent, that precious supply that keeps us alive. The articles range from technical to fanciful. Christopher J. Mundy, Shawn M. Kathmann, and Gregory K. Schenter look at the properties of water, and how it plays its fundamental role in the planet's heat budget and weather systems. Dolly Setton's graphic depicts the many remarkable ways animals have adapted to limited water resources. Merry D. Camhi, who has assisted me in my role as curator of the exhibition "Water: H₂O = Life," which opens this month at the American Museum of Natural History, joins me in a look at why freshwater ecosystems are so vulnerable to declines in biodiversity. Sharon P. Nappier, Robert S. Lawrence, and Kellogg J. Schwab detail the worldwide

the bare minimum gallon-plus per day of safe drinking water, and 2.6 billion lack access to basic sanitation. In contrast, those of us who live in the United States and Canada each consume, on average, more than 150 gallons a day for domestic and municipal purposes (not including agricultural and industrial usage). In the United Kingdom people do fine with about a fifth as much.

People appropriate more than half the world's available surface freshwater. Globally, 70 percent of withdrawals from rivers and groundwater are used for agriculture, 22 percent for industry, and the remaining 8 percent for homes and municipal use. As demand increases, driven by both population growth and soaring consumption rates, water appropriation is projected to rise to 70 percent by 2025. In many ways, we are already damaging the systems that provide us with this critical natural resource.

One-sixth of the world's population cannot access even a gallon of safe drinking water a day.

human health concerns of contamination, pollution, and waterborne diseases. Shea Penland presciently outlined, in the February 2005 issue of *Natural History*, the threat to New Orleans from hurricanes and catastrophic flooding. Now, he gives a sobering appraisal of current "reconstruction" efforts. Chuck Carter's illustration depicts a range of creative high- and low-tech solutions to the challenges of limited or contaminated water supplies. Azzam Alwash describes the heartening recovery of marshlands in post-Saddam Iraq. And Sandra L. Postel explores the politics of water in the Middle East.

Freshwater is not evenly distributed across the globe. The Americas have the largest amount and Oceania (Australia, New Zealand, and the Pacific islands) the smallest. Thinly inhabited Oceania, however, has the greatest per capita supply, more than 9.5 million gallons per person per year. Asia has the lowest. By country, Brazil, Canada, China, Colombia, Indonesia, and Russia together have half the world's supply of freshwater; northern Africa and the Middle East are the water-poorest. The United Nations defines water scarcity as less than 500 cubic meters (132,000 gallons) per person per year. Kuwait has a natural supply only one-fiftieth that amount, but given its huge supply of oil, it can afford to run desalination plants.

At the individual level, further inequities emerge. Although a person can manage for a few days on a gallon or two a day, an adequate supply of clean water is about thirteen gallons per person per day. Ten percent of it is needed for drinking, the rest for sanitation and hygiene (40 percent), bathing (30 percent), and cooking (20 percent). In 2006 the UN estimated that more than a billion people—one-sixth of the world's population—lack even

Groundwater is one of the major systems being stressed. Overpumping, or extracting water faster than the underground systems recharge, has led to plummeting water tables, not only in the Middle East and northern Africa, but also in China, India, Iran, Mexico, and the U.S. The Ogallala aquifer, one of the world's largest, stretches under parts of eight states in the High Plains of the central U.S., from South Dakota to Texas. Water began collecting in porous sediments there some 5 million years ago; a geologically slow rate of recharge means that deep wells still bring up water from the end of the last Ice Age, more than 10,000 years ago, making it truly "fossil water." But the aquifer is being pumped out many times faster than it can be replenished. Between the early 1900s, when the Ogallala was first tapped for irrigation, and 2005, the water table dropped by more than 150 feet in some parts of Texas, Oklahoma, and Kansas. The raising of crops has become uneconomical for some Great Plains farmers, and further depletions could have substantial ripple effects on billions of people around the world who depend on American farm products.

As more land is paved over, rainwater can no longer soak into the ground or evaporate slowly to recharge the system. In coastal areas, a falling water table may open an aquifer to an influx of saltwater, impairing or even ruining it as a freshwater source.

Human activities are affecting other aquatic systems as well. Canals, dams, and levees that impede the natural flow of water can change not only the absolute quantity but the quality of water downstream: its concentration of pollutants, its sediment load, its temperature, and so on. People on both sides of the barrier

are affected, whether they are growing crops or fishing for sport. Those changes can also severely alter or destroy the habitats of other species. More than half the wetlands in parts of Australia, Europe, New Zealand, and North America were destroyed during the twentieth century. When people divert water into desert regions to maintain thirsty crops, luxurious green lawns, and golf courses—instead of growing drought-adapted crops and native and ornamental plants—water resources are decimated. Even high-volume rivers such as the Colorado, the Ganges, and the Nile have been reduced, in some places, to polluted trickles.

In water-rich regions, people may wonder how their actions could have any effect on how people use water in water-deprived areas. But consumer choices obviously help drive what agriculture and industry produce and how they produce it. If agriculture and industry account for more than 90 percent of water usage, our closets, cupboards, desks, and refrigerators are filled with what has been termed “virtual water”: products that require water for their growth, manufacture, and packaging. Those products now come from all over the world, including from places with limited water resources.

More than 700 gallons of water are needed to grow enough cotton to make a T-shirt. Your choice to buy the shirt could lead farmers in arid Central Asia to divert water to irrigate a cotton crop. Although poor farmers may welcome the cash, such diversions have led, for instance, to a 75 percent loss of volume in the Aral Sea. Once the fourth-largest inland body of water by area, the Aral has now shrunk so much that its former lakebed is littered with rusty ships, rimmed with abandoned fishing villages miles from the water's edge, and scoured by storms of toxic dust.

Conserving water helps not only to preserve irreplaceable natural resources such as the Aral, but also to reduce the strain on urban wastewater management systems. Wastewater is costly to treat, and requires continuous investment to ensure that the water we return to our waterways is as clean as possible. During storms, rainwater runs off the pavement, collecting pollutants as it goes. Where storm sewers and sanitary sewers are connected, the influx of storm water can overwhelm sewage treatment facilities, leading to the release of untreated sewage and polluted storm water directly into local waterways. Forty billion gallons of such a toxic cocktail flow into the Hudson River and its estuary each year. Several towns and cities around the world are installing innovative solutions to such problems that also benefit surrounding ecosystems. Rainwater overflow, for instance, can be channeled into wetland systems instead of into storm sewers.

Human activities affect water quality in other ways as

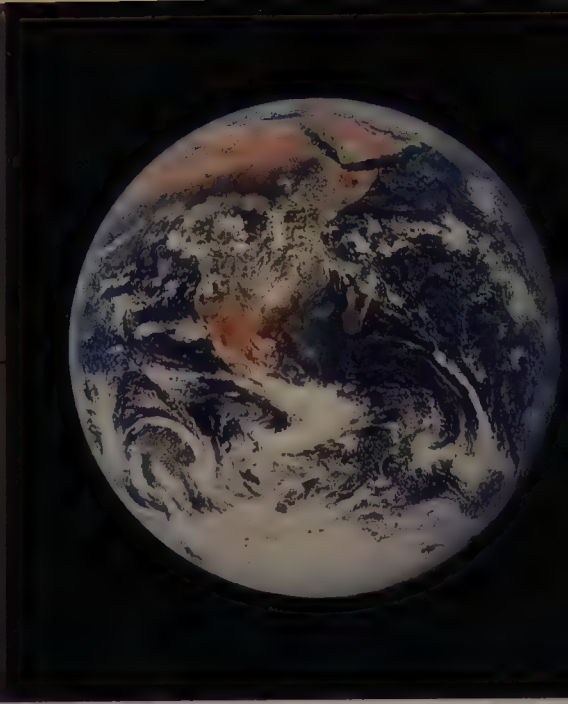
well. Particularly in large cities, once water has disappeared down the drain or into a storm sewer, it is rarely thought of again. But what becomes of the household chemicals poured daily into the water supply—cleansers, antibacterial soaps, medicines? Ecologists are just now learning about their downstream effects. One that is well documented is the disruption of growth and reproduction in frogs and fish. Cities with sophisticated treatment systems can filter out many chemicals, but antibiotics, hormones, and antibacterial compounds remain hard to handle.

The UN estimates that by 2025, forty-eight nations, with a combined population of 2.8 billion, will face freshwater “stress” or “scarcity.” Water shortages already impede development, perpetuate poverty, and damage health in low- and middle-income countries. As populations grow and the demand for water increases, problems will intensify and will not be contained within national borders. Population displacements and conflict over shared surface and groundwater resources are bound to exacerbate international turmoil. It is no coincidence that the word “rival” derives from the Latin word for “one living on an opposite bank of a stream from another.”

The world also faces the uncertain effects of global warming. The loss of mountain ice caps and glaciers, for instance, may alter the quantity and reliability of water for drinking, agriculture, and power generation. California's Central Valley, which produces a quarter of the food sold in the U.S., depends on timely seasonal snowmelt from surrounding mountains; farmers could face failing or lower-yielding crops as the climate warms and less water is available in the growing season.

Water policy makers have focused on technological solutions to increase water supplies—diverting surface water, pumping up groundwater, extracting the salt from seawater. Such solutions often have high costs, both monetary and environmental. And so the focus has shifted to reducing demand. Hydrologists estimate that as much as 60 percent of the water extracted from aquatic systems for human use is simply wasted—lost to leakage, evaporation, inefficient appliances, and human carelessness. Changes in various technologies and in everyday behavior could slash that number in half. Saving water in the home calls for installing water-efficient appliances and fixtures, fixing leaks, refilling water bottles from the tap, landscaping with native plants, and generally being more conscious about water use. Municipalities could construct wetlands or, better yet, refrain from destroying existing ones. Towns and businesses could pave with a permeable material that enables water to seep back into aquifers. Industries and municipalities can reuse water that has been treated but does not reach drinking-water standards. A bounty of choices is available, once we decide to stop taking water for granted. □

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A SPECIAL BREW

Investigators still can't completely explain the strange molecular workings of water.

By Christopher J. Mundy, Shawn M. Kathmann, and Gregory K. Schenter

As children, we have all lain in the grass and looked up at the clouds. Sometimes they seemed to take on the shape of an animal, a favorite plaything, a familiar face. For many of us, such daydreaming segued into a deeper curiosity. What are the clouds? we wondered. What are they made of?

From an adult perspective, the answer seems obvious: water. Stand among the clouds on a mountaintop, and you can feel their moisture. Watch the plump white clouds of a sunny day transform into dark, daunting behemoths, and before long, sheets of water come pouring down. The common wisdom that clouds presage the weather is grounded in a less well known fact: the unique properties of water—in particular, its capacity to transport enormous quantities of energy—are what give the weather its variability, its energy, and its occasional violence.

Of course, our relationship with water goes far beyond the weather. We have fun with it whenever we go skiing or skating, boating, fishing, or swimming. The pleasure of a cold glass of thirst-quenching water on a hot summer day has a more serious basis, though. Without water, a

human being can live only a few days. Every organism is made up mostly of water, and the substance covers nearly three-quarters of the Earth's surface.

Yet this commonplace, familiar, and essential stuff of life is also quite peculiar, as substances go. For example, if the water molecule (H_2O) acted in bulk like other small molecules—oxygen (O_2), carbon monoxide (CO), nitrogen (N_2)—it would be a gas under the conditions prevailing on Earth. Instead, water occurs in all three states of matter: solid, liquid, and gas. Furthermore, water reaches its maximum density in its liquid form, at 39.2 degrees Fahrenheit (four degrees Celsius), just a few degrees above the freezing point. Thus water stays at the surface as it starts to freeze, and ice floats—a rare property shared by very few other substances. If its nature were otherwise, all temperate-zone lakes, ponds, rivers, and even oceans would eventually freeze solid from the bottom up, and life as we know it could not exist. Instead, a floating skin of ice cocoons the life in the liquid water beneath a layer of insulation, enabling it to persist under the frozen surface.

Another unusual and related property of ice is that, for a given temperature, increasing the pressure decreases



Strange properties of water: (a) Cohesiveness enables water to travel upward from roots to leaves, against gravity. (b) High surface tension makes liquid water behave as if coated with an invisible film, which explains why insects can walk on it. (c) Water exists in all three phases—gas, liquid, and solid—at temperatures and pressures that are common on Earth. This familiar property is actually quite unusual. (d) Ice floats on liquid water; unlike most substances, water is most dense in its liquid phase. Lakes and even oceans would otherwise freeze solid in winter. (e) Water's abundance and heat capacity are, in part, responsible for the moderation of global temperature fluctuations and the gradual change of the seasons. (f) Water can dissolve a variety of substances, including acids, bases, and salts, earning it the moniker "universal solvent."

the melting point. (Ordinary solids remain solid under pressure.) Even though these and other unusual bulk properties of water have been described in detail, a complete picture of how and why water acts the way it does is still lacking. It is not possible, for instance, to completely predict the properties of materials that incorporate water in their structure, either physically or chemically, or to design and tune their responses to various conditions. Perhaps the key to achieving that level of understanding and control is to study water on a molecular scale: how water molecules arrange themselves, how they interact, and how they dance with other kinds of molecules. We and our colleagues in the growing field of molecular science hope that by understanding exactly what happens at very small scales (around 10^{-10} meter, or a billionth of a meter), we can zoom out by a factor of a billion or so to understand and predict phenomena on a human scale.

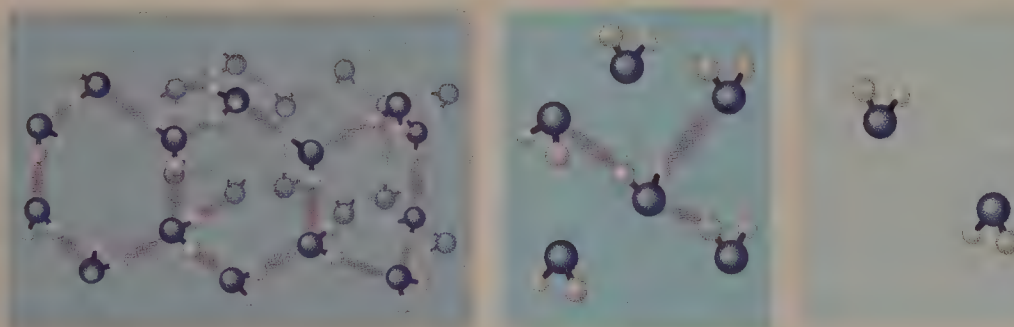
But we don't stop there. Because water is fundamental to

all life on Earth, we also want to zoom out by another factor of 10 million to study its properties on a global scale.

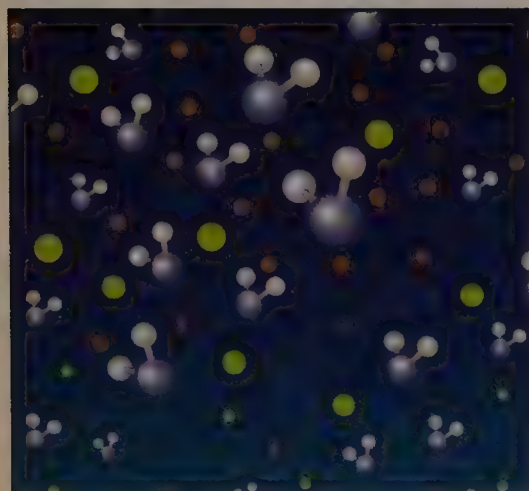
Anyone who has visited the San Francisco Bay area has experienced local climate moderation. The city of San Francisco maintains a mild climate year-round, but just a few miles inland, where hills guard the bay, temperatures can soar to 90 degrees F (32.2 degrees C) in the summer and plummet to near freezing in the winter.

The reason for this contrast, as most residents are well aware, is that the ocean moderates large temperature fluctuations. The same effect, on a global scale, is a factor in keeping seasonal temperature changes gradual rather than abrupt.

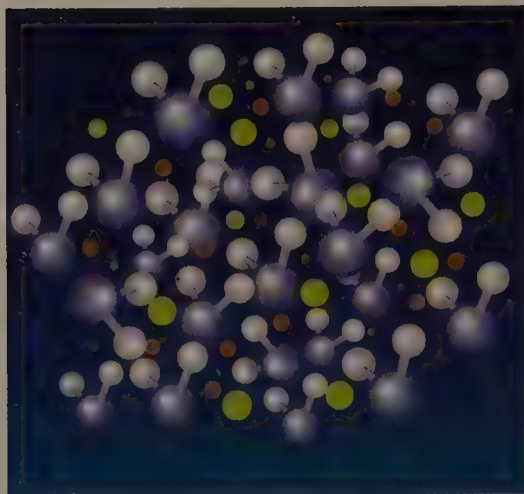
What governs the ocean's moderating effect is the large quantity and heat capacity of water. Heat capacity is the amount of heat energy that must be absorbed or released to raise or lower the temperature by a given amount. For example, it takes four times as much energy to warm a given mass



Ice (left) consists of a collection of hydrogen-bonded water molecules arranged in a pattern of hexagonal rings: oxygen atoms make up the vertices, and hydrogen bonds the edges. In liquid water (center), the water molecules are linked to their neighbors by three to four hydrogen bonds, which continually break and re-form. Water vapor (right), an important constituent of the atmosphere, consists of weakly interacting water molecules.



a



b



c

of water by one degree Celsius as it does to warm the same mass of dry air by that amount. The heat capacity of water acts as a buffer, or perhaps a heavy flywheel, on climate, smoothing out what would otherwise be sharp changes in temperature.

Heat capacity is a good example of a macroscopic property of water that can be explained by what takes place at a molecular level. The chemical formula H_2O , instantly recognized round the world, indicates that the water molecule is a bound system of three atoms, two of hydrogen and one of oxygen. When you add heat (a form of energy) to a macroscopic sample of water molecules, the molecules increase their average speed and collide more often. The temperature of the sample is simply a measure of their average speed. Any energy added to or subtracted from the energy stored as such “translational” motion—movement from one place to another—changes the temperature.

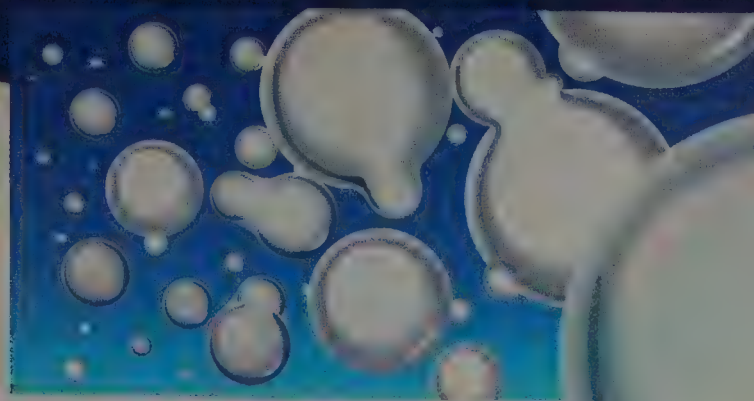
But molecules can absorb and store energy in other ways, too. A water molecule can spin or rotate like a top, or it can wiggle and vibrate. Both rotational and vibrational motion can store energy. Yet they can’t completely explain liquid water’s observed heat capacity. In general, the more ways molecules can absorb heat energy without increasing the average speed of their translational motion—that is, the greater the molecules’ capacity to act as heat sinks without raising the temperature of a substance—the greater the heat capacity of that substance.

You might think that no matter how little energy a molecule may have stored, the energy would still spread more or less evenly among all the possible kinds of motions. In other words, the energy would be partitioned among all possible “degrees of freedom.” Because virtually all molecules made up of three atoms

have the same number of degrees of freedom, their heat capacity, too, should not differ substantially. And sure enough, the heat capacity of the water molecule is about the same as that of other triatomic molecules.

Although the conclusion to the preceding argument agrees with the observed result, the argument itself is faulty. In the world of atoms and molecules, energy cannot be absorbed by the various kinds of molecular motions in arbitrarily small amounts. Rather, atoms and molecules are subject to the laws of quantum mechanics. In the quantum world, all changes in the energy stored by an atom or molecule are *quantized*. Each kind of molecular motion—translational, rotational, and vibrational—can absorb energy only in discrete chunks, whose sizes depend on the details of a particular molecule and the kind of motion involved. Expose a water molecule to the right-size chunk of incident energy (from the Sun, for instance), and the molecule will suddenly rotate or vibrate faster. Expose it to the wrong-size chunk, and nothing will happen; the molecule will simply “disregard” the passing energy. As it happens, the amount of energy available at the normal range of temperatures on Earth is only enough to generate translations and rotations of a single water molecule, but not enough to generate vibrations. Thus, on its own, the single water molecule isn’t enough to explain the heat capacity of liquid water. In fact, the heat capacity of water *vapor* is smaller than that of liquid water by more than a factor of two! So the puzzle reemerges: how can the heat capacity of water be explained from a molecular point of view?

The solution is to look beyond the properties of a single water molecule and consider the interactions among the vast number of molecules in a bulk sample. Begin by considering the interaction of two water molecules. Each molecule is shaped like a tetrahedron, with the oxygen atom at its center. Each of the two hydrogen atoms lies at one of the four corners of the tetrahedron, and each one acts as a center of positive electric charge. When it bonds with hydrogen, the oxygen atom acquires two complementary



d

e

A cloud begins forming (a) as water molecules gather around dust (orange) and sulfuric acid (green) impurities in the air. Attracted by intermolecular forces, more molecules join the cluster (b). Eventually the cluster reaches a critical size—about 50 molecules—of less than 1 nanometer (c). Until this stage, the collection of molecules is highly unstable and may break up. Getting over the energy barrier of the critical cluster constitutes a phase transformation from gas to liquid. The growth process takes off (d) eventually resulting in condensation nuclei, made up of particles that differ in size by a factor of ten or even a thousand. A cloud droplet (e) ultimately emerges, made of 10^{15} molecules; it may eventually grow into a raindrop (f) of 10^{20} molecules.

f

centers of negative electronic charge, which cluster at the opposite two corners of the tetrahedron.

When the two water molecules are brought together, opposite charges attract. One of the sites of positive charge—a hydrogen atom—in one molecule becomes attracted to one of the negatively charged sites associated with the oxygen atom in the second molecule. This attractive interaction is known as a hydrogen bond. In liquid water, each molecule often forms four hydrogen bonds. Two of them link the two hydrogen atoms with the oxygen atoms of two other water molecules [see illustration on page 33]. The other two hydrogen bonds link the oxygen atom with hydrogen atoms of two more water molecules. Those bonds give rise to a stable network of tetrahedral water molecules. In the liquid the network extends only locally, and the hydrogen bonds continually break and re-form. But in ice, the network of tetrahedrons extends over a long range and becomes a relatively unchanging lattice.

Within a network of tetrahedrons, the number of ways incident energy can create rotations, twists, vibrations, and suchlike significantly rises. Each new mode of motion provides an additional degree of freedom, and so the heat capacity of the network far exceeds the heat capacity of a single constituent molecule. Note, though, that many

other molecules, including other triatomic molecules such as carbon disulfide (CS_2), also form linked networks whose heat capacity far exceeds the heat capacity of one of their constituent molecules.

In fact, although it is not widely appreciated, the heat capacity of water, even within a linked network having many degrees of freedom, is not unusually large—provided the heat capacities are stated in units of energy per molecule or per mole, which is 6.02×10^{23} molecules of the substance. On that basis, the heat capacity of water is about the same as that of other triatomic molecules. In the appropriate units, for instance, the heat capacity of water is 75.3, whereas the heat capacity of carbon disulfide is 75.7.

Only when heat capacity is measured in the amount of energy per unit mass does the heat capacity of water look anomalously large. The reason is that the molecular mass of water is small compared with that of other triatomic molecules. Expressed in those units, the heat capacity of H_2O is more than four times that of CS_2 .

The study of the various configurations of the hydrogen bond has made it possible for molecular scientists to explain a number of other anomalies of water. For example, in ice, the hydrogen bonds tend to be slightly longer than they are in the liquid phase, resulting in a larger volume and

thus the lower density of ice than of liquid H_2O . If ice is compressed, the hydrogen bonds shorten and become more like those in the liquid.

Stable hydrogen bonds also lead to the strong cohesive forces underlying the unusually high surface tension of water. Insects such as water striders take advantage of the surface tension when they skip across a pond—as if its surface were made of clear, flexible plastic. And the high cohesiveness and surface tension of water explain how

interaction, the larger the target area onto which more molecules and other nearby droplets can be pulled.

As the water cluster grows, it remains highly unstable until it reaches a certain critical size—the critical cluster—which is about fifty molecules. Precritical clusters can break up at any time into single water molecules. As it approaches the critical size, though, the cluster is also climbing to the “top” of an energy “hill.” If it reaches the top and attains the critical size, it can then “roll down”

In its vapor form, **water** is the most important **greenhouse gas**,
so it plays a **major role** in the **climate** of our planet.

long columns of watery suspensions can be drawn through extensive networks of blood vessels and even into tree canopies several hundred feet above the forest floor.

Water is the third most abundant chemical compound in the Earth's atmosphere, after nitrogen and oxygen. It is present there both as a vapor, or gas, in which the water molecules dart about randomly and independent of one another, and as an aerosol, a mist of tiny liquid droplets or solid ice crystals that are suspended in air because they're too fine to fall to earth as rain or snow. In its vapor form, water is the most important greenhouse gas, so it plays a major role in the climate of our planet.

But when water takes the form of an aerosol, it is crucial to cloud formation and to the reflection and absorption of radiation. Water aerosols act as condensation nuclei for clouds—after all, clouds themselves are made up of relatively large aqueous aerosols. And water aerosols transform radiation in ways that, in turn, feed the factors that shape cloud development. Reaching a better understanding of how water aerosols affect climate has become increasingly important in the past several decades.

Water aerosols enter the atmosphere when waves break in the ocean or when vapor turns to liquid. The latter process, condensation, is in essence a battle between entropy and energy, order and disorder. As water molecules condense into their liquid state, they gain order but lose kinetic energy. The kinetic energy given up by the phase change is dumped as heat into the surrounding air, giving rise to a pocket of thermal instability that will drive yet another change in the weather as it equilibrates.

The physical process of condensation is “seeded,” or nucleated, around tiny molecular impurities or perhaps a dust particle in the air. Once an “embryo” of the new liquid phase forms, more molecules tend to gather around it andglom onto it, attracted by intermolecular forces [see *illustration on pages 34–35*]. The larger the surface area of the growing cluster, or the stronger the intermolecular

the far side of the energy hill and undergo spontaneous, runaway growth. From fifty molecules, the cluster grows and agglomerates to the size of a condensation nucleus (10^8 molecules), then to a cloud droplet (10^{15} molecules), and finally to a raindrop (10^{20} molecules).

In 1998, members of our research team were among the first to measure the chemical identity of the nucleated particles and to show that the chemical interactions among them have a profound influence on the aerosol formation rate. We modeled the rate of evaporation of molecules from clusters, developed a molecular simulation strategy to compute the relevant kinetics, and applied the strategy to water. We found that the molecular interactions between water and the initial nucleating particles—whether dust, sea salt, sulfuric acid, ions, or some other substance—may significantly affect the rate of aerosol formation. That rate affects the distribution, duration, and precipitation processes in clouds, and thus their tendency to reflect, transmit, or absorb the Sun's radiant heat. All those properties in turn influence the reflectivity of the Earth and thus the global climate.

Atmospheric scientists have yet to determine the exact nature of that influence. One possibility is that if cluster droplets grow more quickly, more clouds may form, helping moderate global warming by providing more cloud cover. On the other hand, faster droplet growth could accelerate the production of rain, causing clouds to dissipate sooner. That would lead to a less cloudy world, and faster warming.

As we molecular scientists learn more about water, we are continually reminded that we have merely “scratched the surface” of its secrets. The mechanisms of its impact on life are still something of a mystery. Coaxing Mother Nature to reveal further secrets about water will require the full interdisciplinary sophistication of today's scientific toolbox. But since water is the wellspring of life, we owe it to ourselves—and everyone else—to explore all we can about its strange and intriguing properties. □

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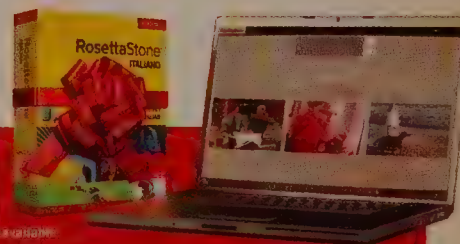
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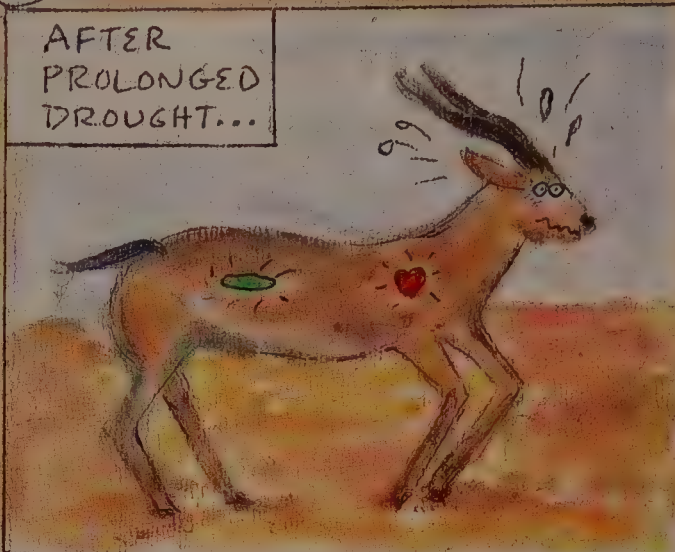
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WATER IN THE WILD

by Dolly Setton

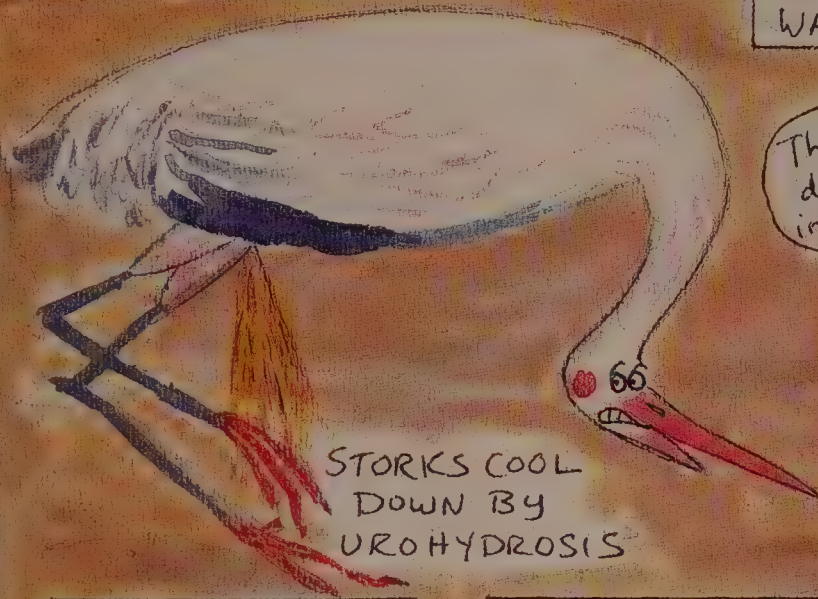


SAUDI ARABIAN GAZELLE



AFTER
PROLONGED
DROUGHT...

THE HEART & LIVER SHRINK AND
BREATHING SLOWS, REDUCING THE
WATER LOST WITH EACH BREATH.



STORKS COOL
DOWN BY
UROHYDROSIS

That stork
doesn't
impress me.

Yeah, we
urinate all
the time!



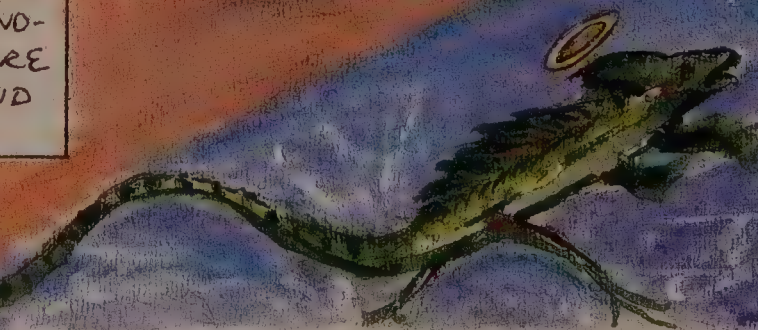
FRESHWATER FISHES KEEP A HEALTHY
BALANCE OF SALT AND WATER BY
RELEASING A STEADY STREAM OF
URINE - IT'S CALLED OSMOREGULATION



NAMIB BEETLE
SCURRIES UP A
DUNE TO CATCH
WATER IN A FOG.



THE BEETLE'S "HAND-
STAND" SENDS MOISTURE
DOWN ITS BACK AND
INTO ITS MOUTH.



JESUS CHRIST LIZARDS - YES, THEIR
REAL NAME! - RUN ON WATER.

NAMIB LIZARDS DANCE ON HOT DUNES AND
GET ALL THEIR WATER FROM FOG

BATS RETREAT
TO CAVES DURING
THE DAY TO STAY
COOL AND CONSERVE
WATER.



GIGGA
GIGGA



OWLS AND QUAILS
FLUTTER THEIR THROATS TO
EVAPORATE WATER AND
COOL THEMSELVES DOWN.

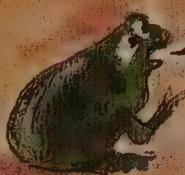
Finally, a bat
signal for bats,
not men in tights!

* THE KANGAROO RAT
CREATES WATER *
* FROM DRY SEEDS. *



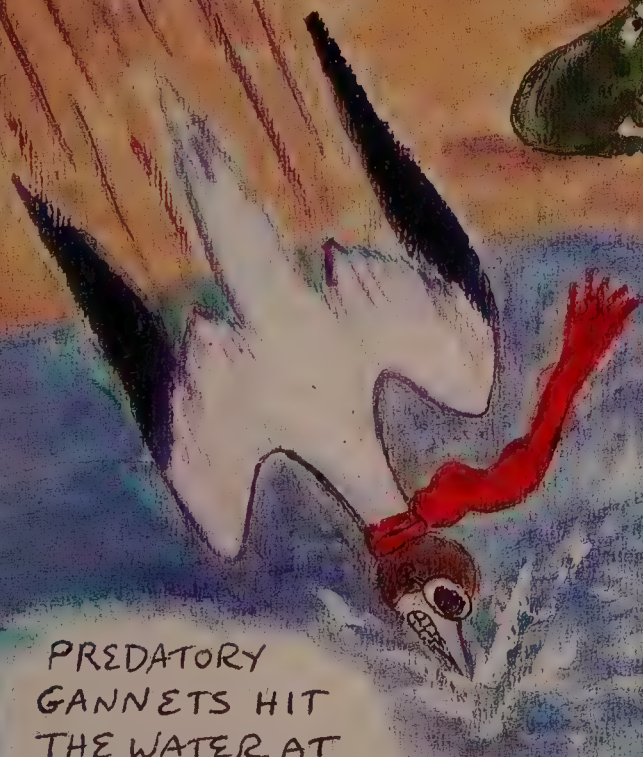
Does my tail
look fat?

Yes, but
that's a
good thing!



GILA MONSTERS
STORE WATER IN
THEIR TAILS.

PREDATORY
GANNETS HIT
THE WATER AT
70 MPH, PROTECTED
BY AIR SACS IN THE
FACE AND CHEST.



BRRRR **EXTREMOPHILES!**



GIANT TUBE WORMS
LIVE WITH THEIR HEADS
IN FREEZING WATER
AND THEIR BUTTS IN
BOILING WATER.

1



How dry
I am.

2



Hallelujah!

TARDIGRADES SUSPEND
THEIR VITAL FUNCTIONS FOR
AS LONG AS 100 YEARS IF
THERE'S NO WATER AROUND.



SOLD DOWN THE RIVER

Dried up, dammed, polluted, overfished—freshwater habitats around the world are becoming less and less hospitable to wildlife.

By Eleanor J. Sterling and Merry D. Camhi

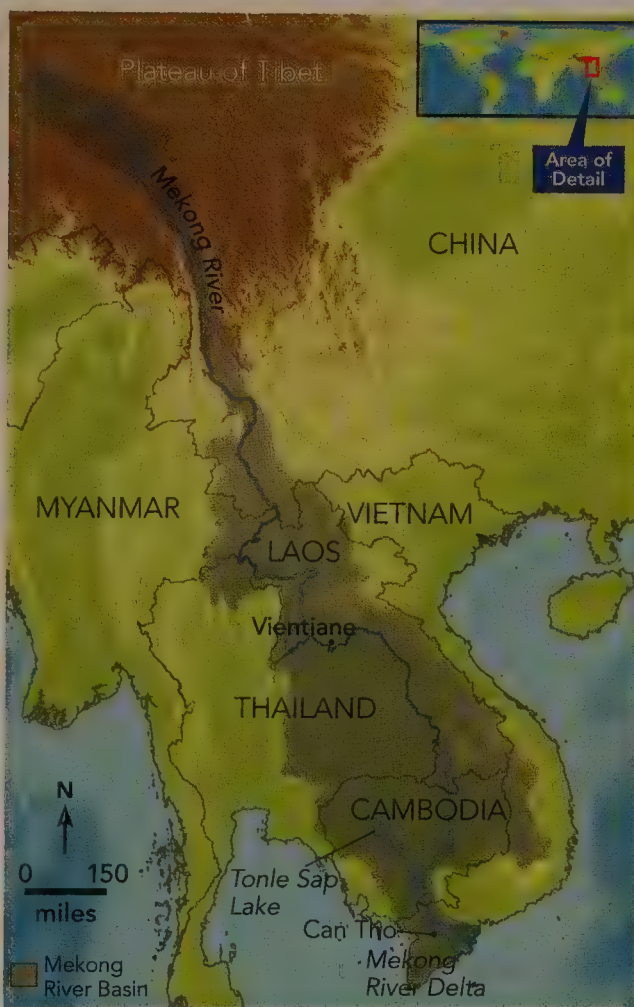


Boat traffic at a floating market near the city of Can Tho, Vietnam, jams a branch of the Mekong River. Some 65 million people live in the 300,000-square-mile Mekong River Basin, also home to a diverse freshwater fauna.

The banks of the Mekong River in Vientiane, the capital of Laos, can be a lovely retreat at sunset. The river sweeps alongside the city in a wide elbow curve, offering a panoramic view of tranquil waters and tree-lined shores. Thailand rests on the opposite bank, seeming farther away than its half-mile distance. And as the setting sun lights the water ablaze, birds skim the surface, and fish make themselves known with the occasional splash, making an evening walk along the riverbank a pure delight.

At the start of a recent visit to Vientiane, however, one of us (Sterling) wound her way through the city to the river, anticipating a cool breeze and a quiet walk after a sweltering workday, only to stare into a scene from the desert. Clouds of dust rose from the riverbed, where a group of kids were playing soccer. Beyond that bone-dry sandbar, a vestige of the river was just visible as a thin stream along the far bank. By all appearances, one could easily have walked across to Thailand.

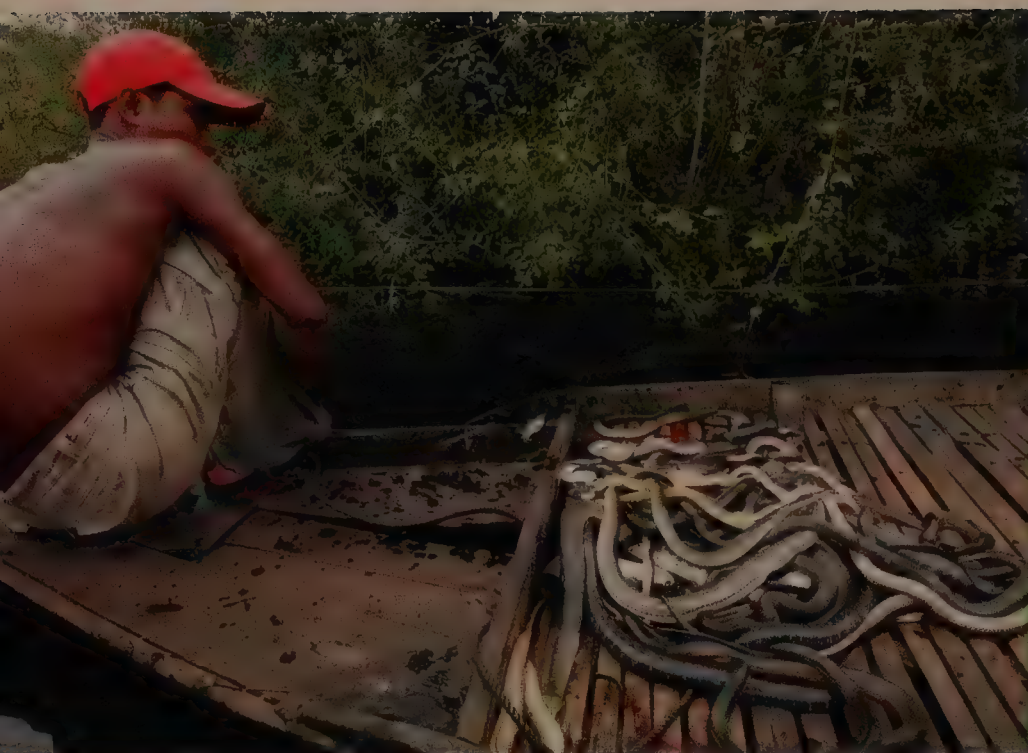
Such radical fluctuations are natural to the Mekong, and whole communities—human and wild—are adapted to its periodic floods and droughts. The river swells when rainfall rushes down its tributaries and shrinks again in drier weather. But the rise and fall of the Mekong is increasingly dictated by energy use in China and Thailand. Upriver hydroelectric dams dampen the fluctuations and change the timing of floods and dry spells, affecting water-dependent wildlife



hundreds of miles away. The extent of those changes is likely to grow as more dams, scheduled for construction, make their mark on the river.

The dams are just one of the many troubles that confront the river and its denizens; water extractions, pollution, invasive species, and overfishing also threaten the ecosystem's health. And the Mekong's woes mirror those of freshwater systems worldwide, which are increasingly pressured by a growing human population that makes ever-greater water demands. The scale is enormous: people now appropriate more than half of the world's accessible surface freshwater, leaving precious little for natural systems and other species to thrive.

As a result, even as the human population of the globe has doubled, many species that depend on freshwater ecosystems have suffered steep declines. The list would bring tears to a conservationist's eyes: in the past three decades, a fifth of the world's water birds, a third of freshwater mammals,



a third of amphibians, and more than half of freshwater turtles and crocodiles have become either threatened, endangered, or extinct. Freshwater fishes represent a quarter of the world's living vertebrate species, and yet more than a third are threatened or endangered. The ecology of freshwater systems may be irreversibly damaged if we humans don't improve the way we treat them.

The Mekong's name translates from Lao as "mother of the waters." It's no wonder: the river snakes some 3,000 miles from its headwaters on the Tibetan Plateau to its outlet through the Mekong River Delta into the South China Sea. It and the uncountable "feeder" rivers and streams in Cambodia, China, Laos, Myanmar, Thailand, and Vietnam make up the 300,000-square-mile Mekong River Basin [see map on preceding page].

That mesh of waterways is one of the most productive and diverse ecosystems on Earth, supporting more than 6,000 species of vertebrates alone. Its fish fauna, with some 2,000 species, of which sixty-two are endemic, exceeds all but those of the Amazon and Congo river basins. The wetlands harbor several threatened and endangered birds and mammals, including the eastern sarus crane, *Grus antigone sharpii*; the Bengal florican, *Houbaropsis bengalensis*; and the hairy-nosed otter, *Lutra sumatrana*, which was recently rediscovered after having been feared extinct. Sixty-five million people live there, too, 80 percent of them dependent on the river for their livelihood as farmers and fishers.

The Mekong River Basin is a microcosm of the Earth's freshwater resources—it includes almost all of the natural forms freshwater takes on Earth: groundwater, lakes, ponds, streams, and wetlands. (Wetlands are defined as shallow, often intermittently wet habitats, such as bogs, floodplains, marshes, and swamps.) Together, freshwater ecosystems cover less than 1 percent of the Earth's surface and hold a mere 0.008 percent of its water, but they support about

100,000 animal species—an inordinately large number for their size relative to marine and terrestrial habitats. That freshwater fauna includes a third of all known vertebrates and a whopping 40 percent of all known fish species.

Their rich biodiversity aside, freshwater systems bestow untold—and underappreciated—benefits on people. Indeed, they are the very foundation of our lives and economies. The value of all the services freshwater ecosystems provide worldwide, such as drinking water, irrigation for agriculture, and climate regulation, has been estimated at \$70 billion per year—a figure that assumes, rather delusionally, that one could purchase the services elsewhere if they became unavailable in nature.

Dams are a dramatic example of a human activity that degrades freshwater ecosystems. Built to control flooding, store water, and generate electricity, dams have numerous ecologically disastrous side effects. They impede the movement and migration of aquatic species; some kill animals in turbines; and they change the timing and amount of flow downriver, which interferes with the reproductive cycles of fishes, frogs, and water birds that depend on seasonal flooding.

About a dozen hydroelectric dams in the Mekong River Basin provide the bulk of the region's energy—and another hundred or so are in the planning stages. To date, China has built two dams across the upper mainstream, but there are none across the lower mainstream—in fact, the Mekong is one of the world's few major rivers with so few mainstream dams. That may soon change: local governments view the free-flowing Mekong as an underutilized economic resource. Worldwide, an average of two large dams have gone up each day for the past fifty years, and today there are more than 45,000 dams taller than forty-five feet. Fortunately, increased awareness of the environmental problems they cause has contributed to a slowdown of



Water-snake hunter, opposite page at left, brings his catch to market on Tonle Sap Lake in Cambodia. The capture of water snakes—mainly to feed crocodiles raised for their hides—has reached unsustainable levels. Workers tend a rice paddy in Laos, top center of these two pages; agricultural runoff degrades the Mekong's water quality. About a dozen dams now partition the river and its tributaries and several more are under construction, including the Nam Theun 2 dam in Laos, above right. Dams provide irrigation water and electricity for the region's growing population, but can harm wildlife.

large-dam construction in the United States and Europe. In the Mekong River Basin and elsewhere, however, big dams continue to rise.

Species along the Mekong, as in other freshwater systems, depend on natural flood cycles for nutrients and for transportation to and from spawning grounds. More than 90 percent of the fish species in the Mekong watershed spawn not in rivers, but in seasonal lakes or periodically flooded forests and fields. Flow patterns altered by dams and other projects could prevent those species from reproducing. In addition to building dams, countries along the Mekong are destroying or modifying rapids and other natural features to improve navigation—changes that will disturb critical fish habitats and alter downstream water flow.

Another destructive practice is crop irrigation, the biggest consumer of freshwater both along the Mekong and worldwide. Most of the water withdrawn from the Mekong goes to irrigating crops, mainly rice. Demand for irrigation water has risen dramatically in the past decade, as new acreage has come under cultivation and new irrigation schemes have enabled farmers to produce a second or third rice crop each year. Removing so much water from freshwater systems can be devastating for wildlife, exacerbating flow problems caused by upstream dams.

Worldwide, irrigation guzzles about 70 percent of the freshwater people use. To grow food for expanding human populations, people divert rivers, drain inland seas, and extract fossil groundwater collected over thousands of years, often at unsustainable rates. Worse, current agricultural

practices often waste as much water as they use: about half the water that flows through conventional irrigation systems never actually reaches a crop plant. A lesser—though still formidable—amount of water is siphoned off to slake the thirst of cities and industry, and when you add it all together, it's clear that people are using more than their fair share. The Mekong still manages to reach the sea. But at least ten other major rivers, including the Colorado, Ganges, Jordan, Nile, Rio Grande, and Yellow, now regularly run dry before they reach their outlets.

Agriculture, in addition to being the greatest consumer of freshwater, is also a major polluter—another bane for wildlife. In the Mekong River Basin, agriculture relies heavily on pesticides and fertilizers; it also drives deforestation, which causes erosion. Chemical, nutrient, and sediment runoff from farms winds up in the Mekong River Delta, where it degrades water quality, shifts natural nutrient cycles, and alters wildlife habitat. The six nations in the Mekong watershed have initiated a regional program to encourage agricultural development. If not done mindfully, the accelerated development could worsen water quality.

Other countries are already contending with the effects of major pollution. Fertilizer, pesticide, and livestock-waste runoff from farms in the American Midwest, for example, have created a dead zone at the mouth of the Mississippi River in the Gulf of Mexico. There, coastal algae populations thrive on the influx of nutrients and the misfortune of their natural predators, which are often curtailed by the pesticides. From spring until late summer, immense algal blooms rob the Gulf's water of oxygen. Such hypoxic conditions chase

the swimming creatures away and kill clams and other sedentary species on the spot. The Gulf's seasonal dead zone now encompasses more than 8,000 square miles, an area the size of New Jersey, every spring and summer. Much smaller dead zones occur on the Mekong, too. Worldwide, there are 146, every one increasing in size, intensity, and often duration.

Besides agricultural runoff, pollution from industry and municipalities is also a big problem for freshwater systems. In addition to contributing extra nutrients that promote algal overgrowth, municipal wastewater also carries thousands of chemicals from products used in daily life: cosmetics, soaps, pharmaceuticals, cleaning supplies, and more. Most of it winds up in aquatic systems.

The long-term consequences of dumping so many chemicals in the water are just coming to light. More than 200 species are thought to have adverse reactions to endocrine disruptors—such as estrogen and its chemical mimics—that get into the environment via human and veterinary pharmaceuticals in wastewater and farm runoff. Sightings of frogs with deformities, such as extra legs, mushroomed in the Midwest about a decade ago. Ecologists think chemicals or an interaction between chemicals and parasites could be causing the deformities. Indeed, chemicals in freshwater may be a factor in the alarmingly sharp worldwide decline of amphibians.

Biological introductions to waterways, like chemical introductions, are extremely problematic. In their own communities, most species are held in check by natural predators or other environmental constraints. But organisms from afar can crowd, devour, or outcompete native species in their new neighborhoods, and can even change entire ecosystems. Most biological introductions by people are accidental, but some, such as fishes stocked for anglers or plants brought in to stabilize soils, are intentional.

Mimosa pigra, a spiny shrub native to the Americas and planted abroad as an ornamental or to control erosion, is now one of the world's worst aquatic invasive species. Once established, it quickly forms dense stands and outcompetes native plants. First spotted on the Mekong in 1979, it spreads in floodwaters and in truckloads of construction sand, and is now devastating parts of the watershed. The mimosa has taken over several irreplaceable wetlands,



Laotian fishmonger offers Mekong giant catfish for sale. The giant catfish, which can grow to nine feet long and 600 pounds, is now critically endangered.

doubling its area almost every year in some places. Several endangered water birds that depend on native grasses for food and shelter are undergoing population declines as mimosa stands replace their habitat.

Controlling freshwater invaders and mitigating the damage they cause costs some 9 billion dollars each year in the U.S. alone. Yet the rate of invasions everywhere is on the rise as global commerce, trade, and travel increase.

So much for the organisms people add to freshwater systems. What about the ones—too many—that we take out? Overexploitation for food, medicine, and recreation poses a major threat to freshwater birds, crocodiles, fishes, frogs, and turtles, as well as some invertebrates. More than 40 million people rely on the waters of the Mekong River Basin for their

protein and income, and they are overfishing numerous species—indeed entire fish assemblages in certain areas—as a result.

The Mekong giant catfish, *Pangasianodon gigas*, is just one of the region's struggling, overfished residents. Reaching nine feet in length and more than 600 pounds, it is the world's largest catfish [see photograph above]. With such grand proportions, a jackpot of succulent flesh that once sold at a premium to urban restaurants, the giant catfish was a fisherman's prize catch. In the mid-twentieth century, hundreds of giant catfish—a naturally rare species—were caught each year, but recently the annual catch has declined to fewer than ten. Overfishing is the main cause of the decline, but habitat fragmentation and alteration of spawning grounds by dams and navigation projects also contribute. Today, the giant catfish is critically endangered, its range is greatly restricted, and the average size of individuals is declining. In recent years, Cambodia, Laos, and Thailand have outlawed catching the giant catfish. But the species is migratory, so a regional agreement may be necessary to prevent its demise.

Fish aren't the only victims of overexploitation. As many as 10,000 water snakes are fished from Tonle Sap Lake each day. The water snakes mainly go to feed hungry crocodiles raised for commercial export; they substitute for fish, whose populations have declined. People are fishing down the food chain in the Mekong River Basin, as in

so many freshwater and marine systems. After depleting the top predators and the largest species, fishermen turn their nets on successively smaller organisms.

The upshot of all those assaults is that freshwater organisms rank among the world's most threatened species. Data on global trends are sparse, but what biologists do know paints a bleak picture of striking declines across taxa. Freshwater dragonflies, damselflies, mussels, fishes, amphibians, reptiles, birds, and mammals—all are suffering. To prevent a wave of irreversible extinctions and ecosystem collapses, people need to take better care of fragile freshwater habitats.

Fortunately, there is much people can do. We can remove obsolete dams and design new ones that take into account natural patterns of river flow. We can reduce the need for massive water extractions by changing the way we grow our food and our cities; more efficient irrigation techniques and increased capture of rainwater, even in wet areas, would help. Conservation may be the best "new" source of water, particularly as climate change begins to shift water supplies globally. We can start to reduce our polluting ways by avoiding harmful chemicals in the first place. In the end, keeping more water in freshwater habitats and maintaining its quality must be a top global priority.

The future of the Mekong lies in the balance. Today, it remains one of the world's least-degraded large rivers,

but the primacy of economic growth threatens to tip the balance towards decline across the entire river system. Still, there are hopeful signs. Several transboundary initiatives are in the works among the six nations that share the Mekong, which should help balance the needs of people and wildlife. Then there's the Mekong River Commission. Formed in the 1950s, the commission has moved away from its original focus on dams and irrigation projects toward more holistic management that takes environmental health into consideration. But the MRC is only as strong as the resolve of the governments it represents; China and Myanmar are not members, which may undermine its effectiveness in protecting the basin.

Internationally, the Ramsar Convention on Wetlands, with 155 signatory nations, guides conservation of 1,675 globally important wetland ecosystems. As with the Mekong River Commission, however, Ramsar's strength rests on the decisions of its signatories: it has no enforcement mechanism. It should come as no surprise, then, that—as with conservation choices in general—most decision makers have consistently chosen short-term economic gain over the long-term health of aquatic systems.

Current societies value few things more than gold. But though one can survive, even live well, without gold, the same is not true for water. Ultimately, the true value of gold is reduced to this: it can buy you fresh, clean water—if there's any for sale. □

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Outhouse in Dhaka, the capital of Bangladesh, provides the only kind of "plumbing" for the surrounding slum. According to the World Bank, one-third of Dhaka's 12 million residents lack sanitation facilities, and almost one-third still lack safe drinking water.

DANGEROUS WATERS

Twenty percent of the people on Earth lack access to clean water. And even that dismal number is likely to grow.

by Sharon P. Nappier, Robert S. Lawrence, Kellogg J. Schwab

An estimated 1,000 new synthetic compounds are introduced every year—some of them inevitably seep into drinking-water sources.

Drought in Australia. Water shortages in northern China. The desertification of western Africa. Almost daily, such headlines roll off the presses and issue from the airwaves.

Undoubtedly, diminished access to freshwater is a dire threat to people around the world. But consider the condition of the water when it finally trickles down people's throats. Infectious pathogens and harmful chemicals—from parasites to poisons—contaminate the world's freshwater and contribute to the deaths of millions of people worldwide every year. Understanding the effects of those contaminants holds the key to protecting our drinking water. And figuring out how we are exposed to harmful agents is the first order of business in choosing proper water-treatment techniques.

The burden of those agents weighs heavily on communities around the world. Nearly 2 million people—most of them children under five—die every year from diarrheal diseases. That statistic is not surprising when you realize just how much dirty water flows, or in many cases lies stagnant, across the continents. Nearly 20 percent of the 6.6 billion people in the world lack access to a supply of clean water, and 40 percent lack safe sanitation facilities. No new headlines there: as far back as 1981 the United Nations recognized the need for improved water supplies and sponsored a water-themed decade through 1990, in hopes of rallying international aid. Yet the percentage of people who have sufficient access to clean water supplies has remained fairly static.

Arguably, the battle is uphill. As quickly as innovative filters and water-transport systems enter the market, new contaminants and diseases arise, populations grow, and competing demands for water increase. Certain microorganisms can be elusive, causing severe illness at doses as low as one infectious organism per drink of water. And those disease-causing organisms don't stand still while we figure out how to combat them: dirty water can lead to increased virulence, as in the case of antibiotic-resistant bacteria. Battling, let alone eliminating, those ever-changing organisms, along with the plethora of synthetic contaminants, seems only to be getting more difficult.

One thing will never change: people need water for survival. Circulating inside, outside, and across our cells, water constitutes as much as 70 percent of our body weight. Although we may survive four weeks without food, our bodies last, at best, only a few days without water. Furthermore, we use water for the most basic daily activities: drinking, cooking, bathing, washing, and sanitation.

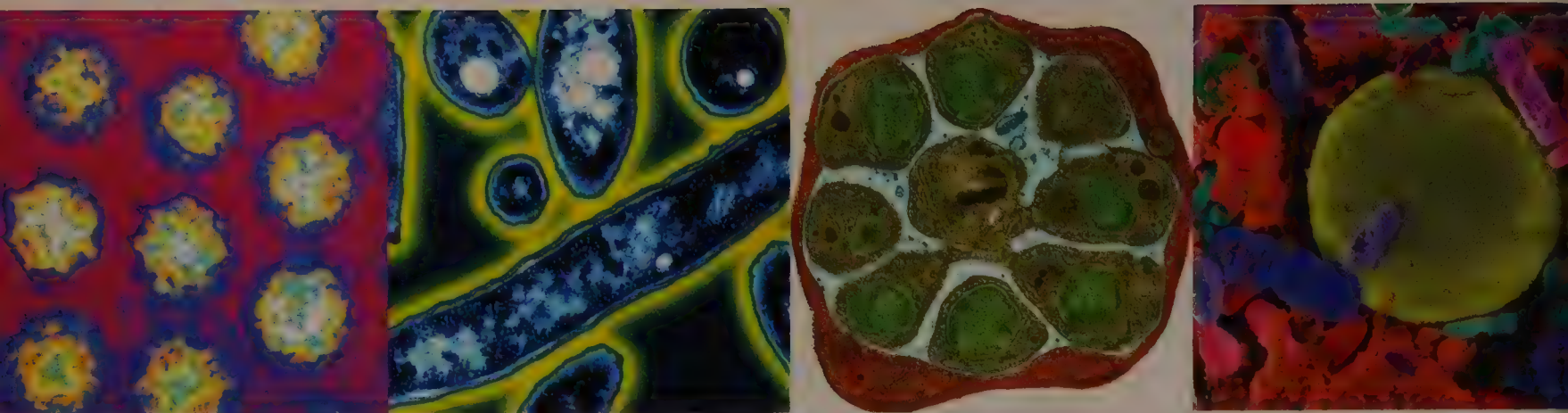
For at least the past six thousand years, civilizations have understood the need to engineer water treatment techniques. Greek and Sanskrit texts discuss approaches to water sanitation that include boiling, straining, exposing to sunlight, and charcoal filtering. The ancient Egyptians employed coagulants—chemicals that are frequently used even today to remove suspended particles in drinking water—and other methods of purification. The earliest large-scale water treatment plants, such as the one built in 1804 to serve the city of Paisley, Scotland, used slow-sand filtration. By the 1850s London was sending all of its city water through sand filters and saw a dramatic reduction in cholera cases.

The discovery of chlorine as a microbicide in the early 1900s was a turning point in drinking-water engineering. That, in turn, led to a major advance in public health. Chlorination was initiated in the United States around 1910, and during the next several decades change was evident: the previously high mortality rate from typhoid fever—twenty-five deaths per 100,000—plummeted to almost zero. Although chlorine readily inactivates viruses and bacteria, its killing power flags when faced with hardy protozoan oocysts (developing cells), such as those of *Cryptosporidium parvum*—an agent of diarrheal disease. Another, and perhaps even nastier, drawback is that chlorine and organic matter may create carcinogenic by-products when they mix in the treatment plant. Nevertheless, chlorine is still one of the cheapest and most effective disinfectants in use today.

No panacea for water disinfection exists, however. To ensure that the water supply is clean enough to drink, most modern drinking-water plants amass an arsenal of treatment options. A multibarrier approach might include physical processes such as coagulation and flocculation (creating clumps of particles), sedimentation, and filtration, in conjunction with disinfectants such as chlorine, chlorine dioxide, chloramines, or ozone.

Such systems for cleansing community water are public investments that pay dividends. Clean water improves general health and reduces health-care costs, thereby enabling greater productivity among community members and redirection of public funds to other pressing needs. Unfortunately, rural and low-income localities cannot afford the infrastructure required for large, centralized drinking-water facilities.

On a global scale, of course, an ideal filter is natural vegetation. Protecting entire watersheds could vastly im-



Water-associated pathogens that threaten human health include, from left to right, Norovirus, the Norwalk virus; Legionella, the bacterium responsible for Legionnaires' disease, a kind of pneumonia; Plasmodium, the protozoan that causes malaria (pictured here inside a red blood cell); Cryptosporidium, a protozoan that causes severe diarrhea and resists treatment with chlorine; Vibrio cholerae, the cholera bacterium; and Giardia lamblia, another protozoan that causes diarrhea.

prove water quality worldwide; benefits could come from actions as simple as maintaining hillside growth to prevent soil erosion and flooding. But because many watersheds span several states or even countries, most management plans are politically complex. A comprehensive watershed-management plan must incorporate multiple stakeholders' needs and conflicting interests.

Water scarcity goes hand in hand with disease. As renewable freshwater becomes a dearer commodity worldwide, waterborne disease agents and other contaminants become harder to control. When dealing with diarrheal diseases, for instance, the quantity of available water often matters more than the quality, both to fend off the disease and to foil its spread. Then there's trachoma, a condition that can cause blindness; today it affects 6 million people and is associated with poor personal hygiene, often resulting from a dearth of water.

Every person, every day, needs at least thirteen gallons of water for drinking, cooking, bathing, and sanitation. In 1990 more than a billion of the world's people used less than that. By contrast, average per-capita water usage in the U.S. now exceeds 150 gallons a day. That discrepancy illustrates how the level of personal use correlates not only with the economic development of a region, but also with the degree of urbanization and with the overall public health in the region.

All that water filling swimming pools and soaking gardens might seem extraordinarily wasteful, but only 8 percent of the planet's freshwater supply goes toward personal, household, and municipal water use. Agriculture accounts for 70 percent, and industry for 22 percent, of current freshwater use. It takes more than fifty gallons of water to produce a single cup of milk. That's modest as virtual water content goes: consider a quarter-pound hamburger (470 gallons) or a cotton T-shirt (520 gal-

lons). Then consider how many cotton T-shirts are tucked away in your closets. It's no surprise that demand is exceeding supply.

Daily water needs are exceedingly hard to meet in areas where rapid urbanization is taking place. Antiquated water-supply systems are simply not equipped to provide enough water and sanitation to people living in progressively crowded shantytowns or on the urban fringe. About half the world's people are now city dwellers. This new urban majority puts great stress on infrastructure, increasing the likelihood that illegal connections will be inserted into existing water systems and that, as a result, the piped drinking water will become contaminated.

Countries undergoing urban population booms often face acute microbial hazards. In countries where per-capita income is low, roughly 200 children under the age of five die every hour from a water-associated microbial infection. Many of the infections derive from the ingestion of water contaminated with human or animal feces that carry pathogenic bacteria, viruses, protozoa, or helminthes. That's the classic, but not the only, pathway for waterborne disease spread.

Exposure to contaminated water extends beyond the drinking fountain. Many diseases, once introduced into a population, can spread via person-to-person contact, in aerosol droplets, or through food preparation, rather than direct consumption of contaminated water. For example, malaria-carrying mosquitoes use stagnant water as a breeding ground; *Giardia* can be acquired during a swim in a local lake; clothing or bedding may carry scabies mites; noroviruses can be transmitted by eating oysters [see photomicrographs on these two pages].

Emerging infectious diseases (the ones whose incidence in humans has increased in the past two decades or threat-



ens to increase soon) have recently caused some public-health scares. Noroviruses—headlined for causing cruise ship infections—are already on the rise. *Cryptosporidium parvum* sickened some 400,000 residents of Milwaukee, Wisconsin in 1993, when the local water-treatment process was changed in what had seemed to be a minor way. *E. coli* O157:H7 is another of the more common emerging infectious pathogens in the U.S. joining the hefty ranks of dangerous bacteria, many of which are becoming resistant to multiple standard antibiotics.

But pathogenic microorganisms are not the sole cause of water-associated illnesses. Chemicals, too, pose serious risks. About a thousand new synthetic compounds are introduced every year, joining the ranks of tens of thousands more that are already in widespread use—dioxins, PCBs, and halogenated hydrocarbons included. Many inevitably seep into the water system and accumulate in the food chain. In the United States, for instance, some 700 chemicals have been detected in drinking water sources, and more than a hundred of those chemicals are considered highly toxic.

Advanced technologies enable investigators to detect harmful chemicals in the water supply, even in low concentrations—a critical step, since their effects on human health are often unknown. Several emerging chemicals

of utmost concern are fuel additives, such as methyl tertiary-butyl ether, or MTBE; by-products of disinfection; antibiotics, hormones, and psychoactive drugs; the antibacterial soap ingredients triclocarban and triclosan; and persistent organic pollutants, such as perfluorinated chemicals and phthalates.

Most people have a sufficiently robust immune system to handle exposure to a certain amount of water pollutants. But some—infants, the elderly, people living with cancer or AIDS—are immunocompromised. Elderly adults often sicken on exposure to only a small fraction of the infectious dose that others require—an issue for the U.S. as its baby boomer population ages.

Just as an aging population poses a concern for public health, so too does an aging infrastructure pose a concern for water delivery. U.S. water infrastructure is outdated and deficient. In the next few decades, measures must be taken to reinforce or restore our water delivery pipes and systems, equipping them for both natural disasters and terrorist threats.



Drawing copied from the wall of an Egyptian pharaoh's tomb—dated to about 1450 B.C.—depicts an early method of water purification. One person, shown on right, pours water into the purifier, while another, shown on left, appears to use suction power to draw the water through a series of filters.

Once again the United Nations has declared a water decade: 2005 through 2015 will be the Water for Life Decade. Among the UN's Millennium Development Goals outlined for the decade are reducing the number of people worldwide who lack adequate water and sanitation by half. Additional efforts will concentrate on curbing the unsustainable exploitation of water. As with the UN's approach to increasing literacy, facilitating income generation, and curbing population growth, the focus will be on empowering women as a means of achieving its goals.

Certainly the goals are challenging. Achieving them will require cooperation among many stakeholders who are committed to

expanding investments in water and wastewater infrastructure. New management strategies must embody conservation and efficiency for people everywhere, lest we find ourselves changing too slowly to quench the world's thirst. □

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WHEN THE SEAS COME MARCHING IN

Hurricane Katrina exposed fatal flaws in the flood defenses of New Orleans. Those flaws remain.

By Shea Penland



If you live in Louisiana and don't know how to swim, now might be a good time to learn.

—Shea Penland, “Taming the River to Let In the Sea,” *Natural History*, February 2005

Less than seven months before hurricanes Katrina and Rita brought indescribable devastation and heartache to the Gulf coast, I warned the readers of this magazine, in the words quoted above, of the inevitable path toward destruction that New Orleans seemed determined to take. Of course, my near-term prescience was unintentional, but my advice is still sound: even if recent initiatives prove successful, you'll need at least a pair of waders. Since the hurricanes hit, committees have been formed, surveys have been commissioned, consciousness has been raised. Most of the attention has gone into investigating how the levees failed and how best to rebuild them, even though overambitious flood control was a prime cause of the conditions that made Katrina and Rita so deadly.

Hundreds of years of natural-resource exploitation and modifications to the flow of the Mississippi River—whose silty waters created the delta region of southern Louisiana—have cost the state more than 1,900 square miles of coastal wetlands in the twentieth century alone. The U.S. Geological Survey estimates that 213 square miles turned into open water between the fall of 2004 and the fall of 2005. Natural History asked for my reassessment of the issues I raised from today's vantage point, two years after the hurricanes. Because so little had been done to address the underlying problems, it seemed apt to restate, in somewhat shorter compass, what I said at that time. My hope continues to be that someone will listen.

Every year the threat of hurricanes looms. The accompanying storm surges cause local, short-term flooding, but they also erode away parts of the coastal marshes and barrier islands that provide the only

Work continues on the floodgates of the 17th Street Canal levee. A breach in the levee flooded the Lakeview area of New Orleans with more than ten feet of water during the aftermath of Hurricane Katrina.

protection for the inhabited lowlands farther inland from the Gulf. Louisianans have focused on river flooding for hundreds of years, yet only in the mid-1970s did the state begin to take seriously the problem of coastal erosion.

Important as they are, though, beach erosion and flooding are still not the heart of Louisiana's problem. That, in a few words, is subsidence of the delta plain.

Before the levees were built to channel and “control” the Mississippi and other nearby rivers, floodwaters would spread out and slow down as they flowed over the delta. When the flow slowed, the river deposited its burden of silt, forming a new layer of earth. But the levees, which now constrict floods along a 1,200-mile corridor of the Mississippi, prevent the floodwaters from spreading across the delta. As a result, the river-borne silt is lost off the edge of the continental shelf.

The delta, primarily mud that had already filled the Mississippi River valley before the levees were built, is continuously being compacted under its own weight. As it compacts, it loses elevation, and without floods, no new sediments can arrive to build the land back up. In the past several hundred years, subsidence rates have ranged from one foot to four and a half feet per century.

Compounding the risk of catastrophic flooding is global climate change. Many climatologists expect such change to cause hurricanes even more frequent and more violent than those of the past several years. Sea levels are expected to rise by ten to twenty inches.

The threatened collapse of coastal Louisiana has been centuries, even millennia, in the making. Eighteen thousand years ago, toward the end of the last ice age, sea levels began to rise dramatically. For thousands of years the great glaciers that had formed in the preceding era melted into the ocean. Eventually, four thousand years ago, the sea level stabilized. But the Mississippi now met the sea in what had been its old valley. The river water, halted in its course by the Gulf of Mexico, no longer held sufficient energy to carry its sediment. Falling out of the flow, the sediment began to fill in the ancient river valley. The result was a subsidence-prone delta that could maintain its elevation only as long as sediment from upstream reached the delta plain each year.

Meanwhile, over the millennia, the Mississippi Delta has undergone a process known as delta-lobe switching. The path the river takes to the Gulf of Mexico is continually changing, because the river is continuously drawn along the most efficient path to the Gulf.

In the 1940s, in response to findings that the Mississippi was about to switch course again, the U.S. Army Corps of Engineers built a massive concrete structure known as the Old River Control Structure, at the confluence of the Red and Mississippi rivers, where the Atchafalaya begins. This structure controls the volume of water that flows down the Mississippi, allowing no more than 30 percent



of the flow to enter the Atchafalaya. The remaining 70 percent continues past Baton Rouge and New Orleans to the Mississippi's present delta in the Gulf. With the completion of the Old River Control Structure, the Mississippi River appeared tamed.

It was obvious even in the 1950s that the sediments created by the perennial spring floods were no longer reaching their natural resting grounds in levees, swamps, and marshes. At the time, that seemed a blessing. The primary effect, however, was to restrict sedimentary land buildup to two isolated locations on the coast: at Head of Passes, seventy miles southeast of New Orleans, where the



Wetlands in New Orleans. One restoration project, which has been operating since 1991, pumps freshwater into wetlands below New Orleans. The project is intended to mimic the natural over-bank flooding that built the delta in the first place. The project is a valuable model for restoration techniques, but it has had the unwanted effect of disrupting seafood harvesting.

Mississippi River reaches the Gulf, and at the Atchafalaya River outlets, south of Morgan City. Elsewhere across Louisiana, coastal land loss continued to worsen.

But the downside of flood control is not limited to restricting the natural dispersal of sediments. It also interferes with the dispersal of nutrients across the delta. Even before the twentieth century, conservationists noted that alterations to the river were causing entire ecosystems to decline at some distance from the main stem of the river. Years after the levees and spillways were completed, investigators from the Louisiana Universities Marine Consortium discovered a "dead zone" of water spreading out into the Gulf of Mexico from the shoreline at the mouth of the Mississippi. At times it covered an area as large as New

Jersey. Devoid of dissolved oxygen, the dead zone owed its existence to massive flows of fertilizers collected by the Mississippi and its tributaries.

Flood control and its multiple ramifications had set the stage for disaster.

In 1989, finally prodded into action, the Louisiana legislature established the Louisiana Wetlands Conservation Authority, and Congress subsequently passed the Coastal Wetlands Planning, Protection, and Restoration Act of 1990 (CWPPRA). By then, the total funding for various state and federal coastal restoration programs in Louisiana exceeded \$50 million a year.

One of the first restorations was the Caernarvon Freshwater Diversion Project, which began operating in 1991. Planned prior to CWPPRA, the project called for discharging as many as 80,000 gallons of freshwater per second into the swamps, marshes, and shallow bays east of the Mississippi River and downstream from New Orleans, in Saint Bernard and Plaquemines parishes. The project consisted of a set of diversion gates built through the existing flood-control levees; the flow through the gates was intended to mimic the natural over-bank flooding that had built the delta in the first place.

Since 1991 the Caernarvon project has become a model that has afforded valuable practical experience with restoration techniques. It has also had unwanted effects. For example, the freshwater diversion project disrupted seafood harvesting by coastal communities, and as a result of lawsuits brought against the project, local oystermen have been awarded more than \$1 billion in damages.

From 1991 until 1998, more than forty-five projects were begun under the auspices of the CWPPRA. But it soon became obvious to both state and federal governments that addressing coastal land loss in Louisiana far exceeded the scope of the original CWPPRA legislation. A new effort, known as Coast 2050, was set up to evaluate and plan for a larger-scale restoration of coastal Louisiana. That work resulted in a plan with an anticipated price of \$14 billion. The Coast 2050 effort subsequently evolved into the Louisiana Coastal Area Ecosystem Restoration Project, or LCA, in which I participate as a geologist.

More than a hundred restoration projects are now active, but they are experimental, and their scale is such that even collectively they have relatively little impact on the fundamental problems. In the wake of the storms of 2005, however, public sentiment would support a more comprehensive effort to address coastal restoration.

There is no handbook on the subject. What we already know and what we are learning is contributing to the foundation of the emerging field of environmental restoration science. If we can apply the science fast enough, we may be able to keep Louisianans' homes and heads above water. The overriding lesson we've learned is the deadly hazard of playing around with rivers. □

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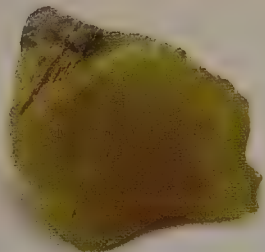
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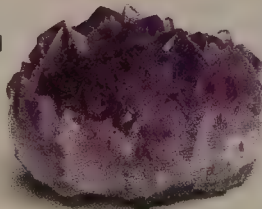
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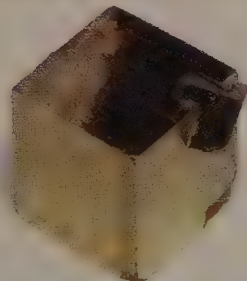
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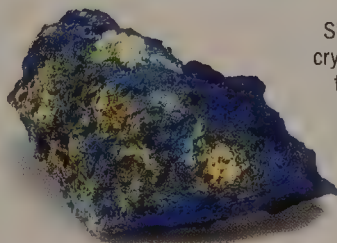
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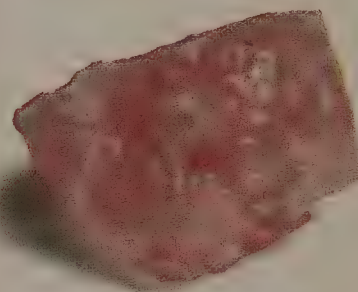
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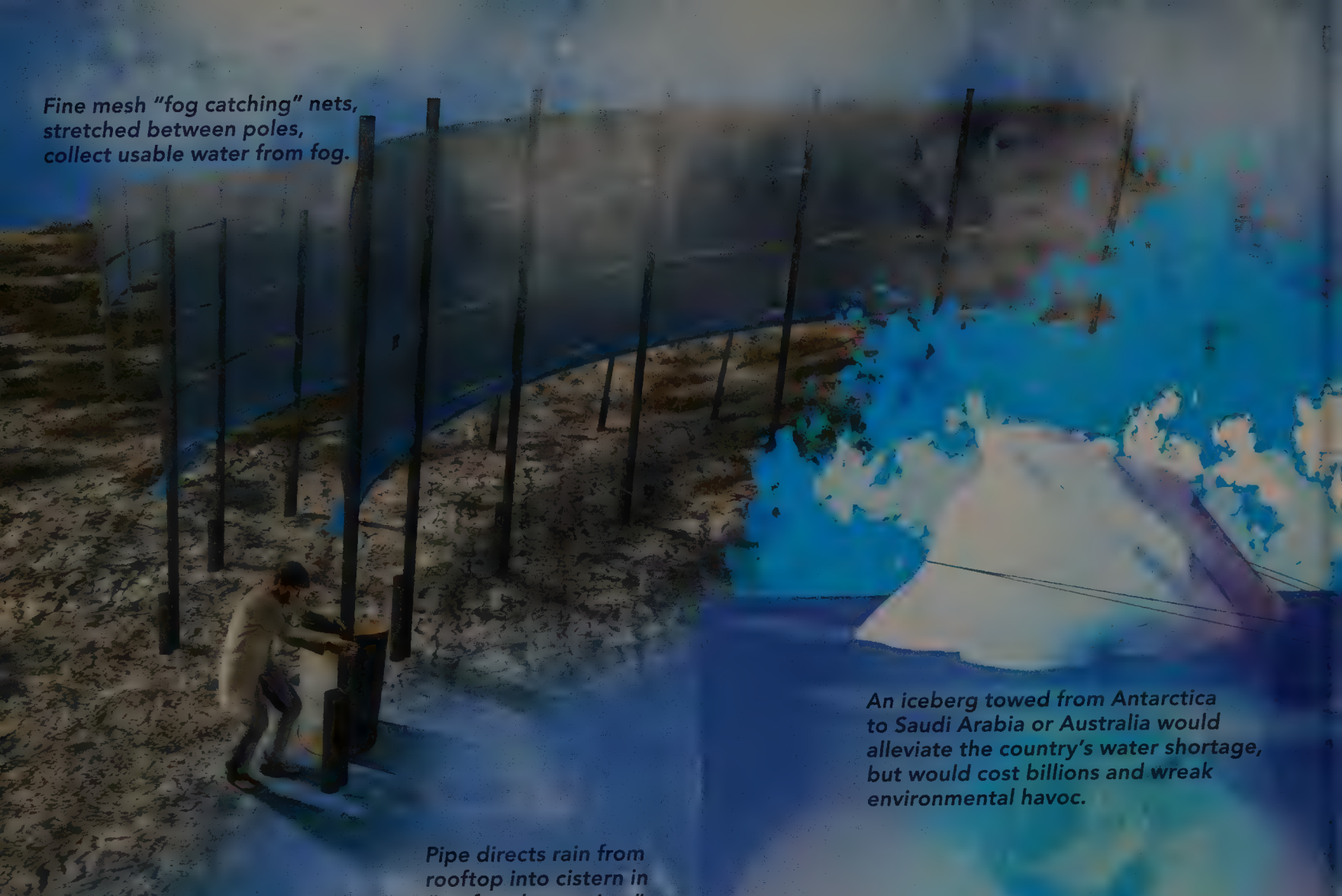
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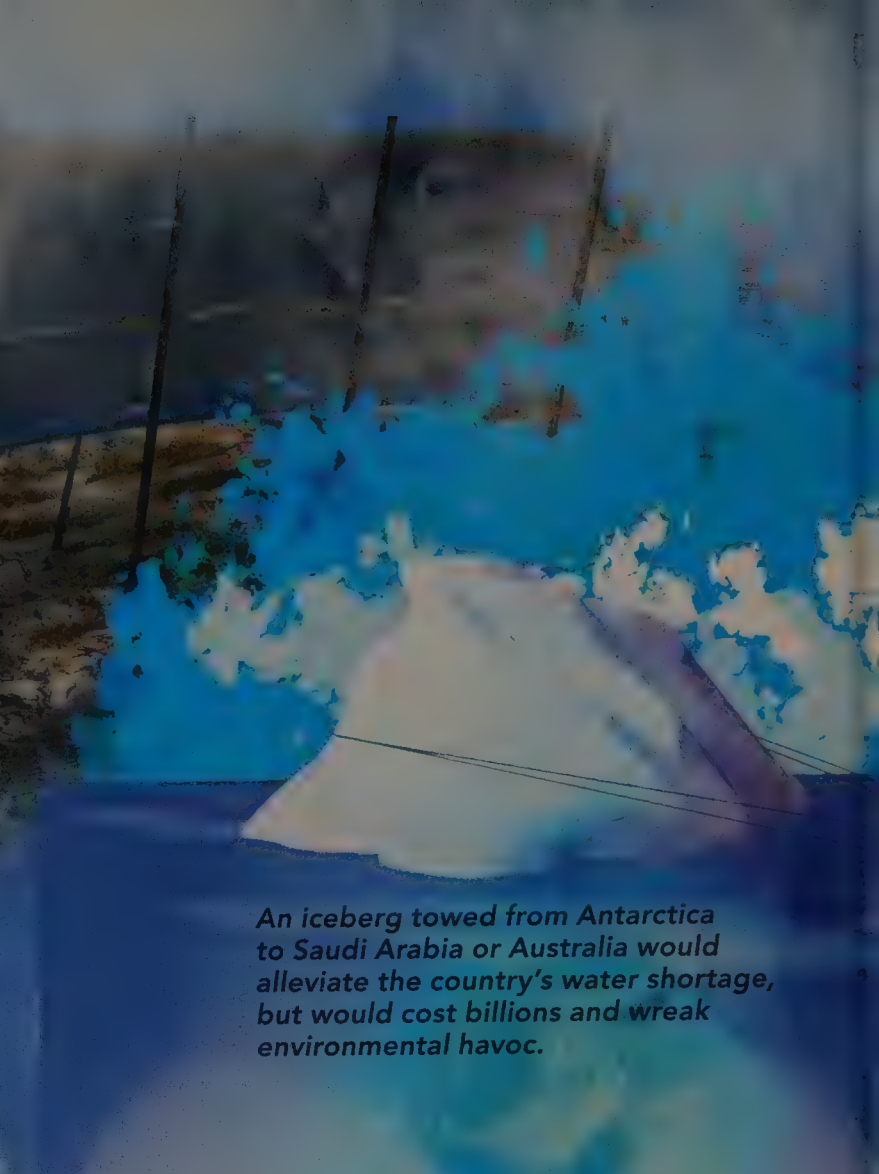
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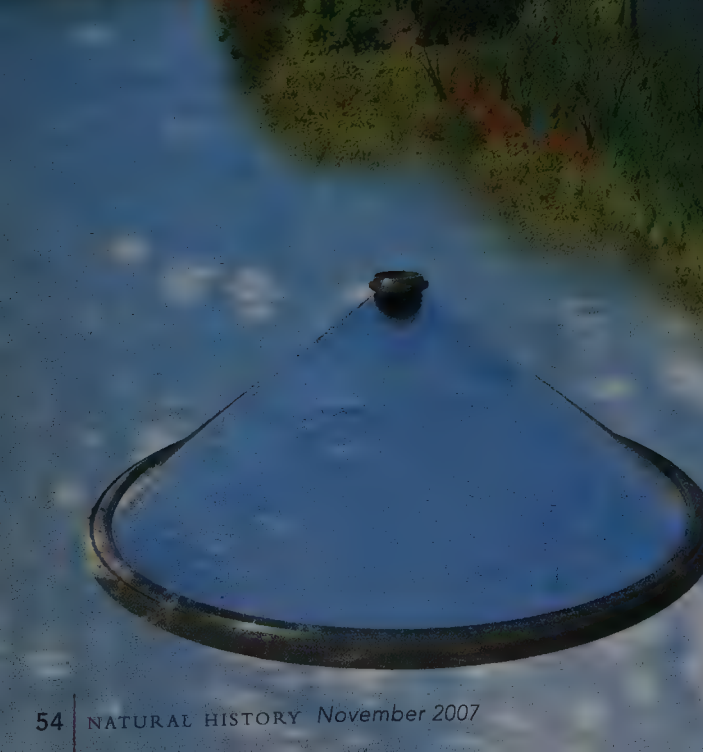
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Desalination cone placed over saltwater in the sun evaporates the water, which condenses on the cone's inner wall and trickles down into a collection channel around the bottom edge.

HYDRO TECH

Illustration by Chuck Carter

A bamboo treadle pump, made of inexpensive local materials, helps farmers tap groundwater to irrigate small plots of land.

A wind-powered spray turbine mounted on an anchored platform in the ocean sucks water up through pipes, then filters and sprays it in fine droplets into the sky. The humidified air produces clouds and rain.



The fine weave of women's old saris, folded four times, can filter out cholera-causing bacteria.

WATER AT WAR

Iraq's marshlands, once decimated by Saddam Hussein's campaign against his own people, are reviving with global aid.

By Azzam Alwash

When I was growing up in southern Iraq in the 1960s, my family used to take me on picnics to the Great Ziggurat temple and the royal burial grounds of Ur, about 140 miles northwest of the Persian Gulf. I remember the massive brick structures jutting up from a stark landscape, in contrast to my verdant hometown of Al-Hillah—once ancient Babylon—fed by the Euphrates River. Little did I know that my desert playground at Ur once sat on the shoreline of the Gulf, at the mouth of the Tigris and Euphrates rivers. The dry, ashen dirt where I played had been the center of a bountiful oasis where ancient kings had ruled and ancient priests had appeased their gods, a place that often bears the title “cradle of civilization”: Mesopotamia.

Five thousand years ago the entire region was lush, fertile—an ideal birthplace for human civilization. Archeological studies published this year show that between 3000 B.C. and 2000 B.C. a concatenation of cities stretched eastward from Mesopotamia all the way to modern-day India and Pakistan. Yet the most extensive evidence of urban evolution comes from the old riverbanks of the Tigris and Euphrates. Solid wheels were used, and perhaps invented, there. Organized cultivation of wheat and barley began on those marshy shores. The cities' inhabitants developed a written language. And a distinct separation between state and temple was recorded.

By the time I was playing on the remnants of ancient Ur, many environmental changes had taken place. Droughts, changing river courses, and silting of the river outlets into the Gulf had pushed the coastline southward and the giant rivers eastward. Yet the Tigris and Euphrates were still infusing the land with life, a land said to have been the biblical Eden. In the 1970s 8,000 square miles of wetlands provided a home to hundreds of species of wildlife, as well as to people—the Marsh Arabs, or Ma'adan—whose ancestors



had been thriving in the watery environment for centuries. Then the entire ecosystem crashed.

The region's worst environmental disaster in the history of human civilization took place in a single decade of my adult life. In the middle of the Iran-Iraq war, which lasted from 1980 until 1988, Saddam Hussein's regime began using water as a weapon, and a weapon of mass destruction at that. Supply roads were cut through the marshes, and large tracts were dried and then reflooded for strategic purposes, as Saddam's army blocked Iranian advances and hunted political enemies and weapons smugglers. But it was after the end of the first Gulf War in 1991, when the Ma'adan rose up with other Shi'a Iraqis against the regime (expecting U.S. help that never came), that the assault on the marshes began in earnest. Saddam Hussein's army dammed the rivers and dug extensive canals to divert the water and drive out the insurgents. The soldiers also contaminated the marshes with pesticides and pulsed high-voltage electricity through the water to kill whatever life might have remained.

Before 1990, the Tigris and Euphrates brought 25,000



Iraqi marshland scenes from the early 1970s (top row, from left to right): an elderly Ma'adan, or Marsh Arab, drinks tea; a Ma'adan village floats in open water; villagers collect reeds used for houses, fodder, and fuel; men in a motorboat tow two canoes. Present-day images mark the changes wrought by time, war, and restoration efforts (bottom row, from left to right): the Great Ziggurat in Ur sits far from the Persian Gulf; desiccated land lacks the wildlife once abundant there; a boy pilots a boat on a lush, reclaimed section of the Hawizeh Marsh; a mortar lies in dry dirt—a reminder of the work yet to be done.

billion gallons of water through Iraq each year. More than 60 percent of that flow came from the mountains of Kurdistan in spring, fed by melting snow. The low-lying marshes acted as a flood basin, annually refreshed with a large supply of freshwater that was laden with nutrients. The spring flooding of the marshes coincided with the spawning of several fishes and the end of winter dormancy for reeds, and ushered in the annual migration of more than 200 bird species between Siberia and Africa. The Basra reed warbler, the Dalmatian pelican, the Goliath heron, the grey hypocolius, the marbled teal—all thrived in the reedy haven, an ecosystem that lived by the annual pulse of fresh water.

For millennia, people also relied on the regular influx. Sumerian farmers lived around the perimeter of the marshes and profited from the new layer of silt and clay swept in every year, which renewed the vitality of their

farmland. Barley, wheat, and rice flourished in the long, moist growing season.

The marshes also provided the ancient Sumerians and some of their descendants—the Ma'adan—with plentiful fish and wildlife, not to mention an unusual source of construction material: reeds, particularly *Phragmites australis*. That species, which is treated as a pest in the United States, grows as high as thirteen feet tall. The Ma'adan cut and bound the reeds together to make huts and even islands atop the surrounding water. The reeds were fed to water buffalo and cattle, burned as fuel, bound into boats, and woven into mats. In more ways than one the reeds served as the scaffolding of the marshland. The thick reed growth helped to slow passing water and trap fine soil particles; some pollutants were absorbed and processed; organic matter built up and supported microscopic life, which in turn fed larger creatures. The overall effect was to turn the northern reaches

of the Persian Gulf into a haven for oysters and rich coral beds, on which the pearl divers of Kuwait made a living before oil was discovered. And before 1990—a turning point in Saddam's tightening control over the waterways of Iraq—more than half the fish consumed throughout the country came from the three main marshes in Iraq: Hammar, Central, and Hawizeh [see map below].

In 1991, when Saddam's forces were driven out of Kuwait, many Iraqi civilians revolted against their government but were defeated by the remnants of the Iraqi army. The rebels who could went into exile abroad, but the ones who couldn't went into the marshes with the Ma'adan. The watery world of the marshes provided food and easy shelter, and the soggy ground proved to be an insurmountable obstacle to the armored vehicles of the Iraqi army.

The marsh dwellers continued to harass the army units until Saddam decided to take drastic action against them. And so began an incredible engineering feat of destruction. Hundreds of miles of canals were dug to divert the waters of the Tigris and Euphrates away from the marshes, choking off their source of life. Acres upon acres of reeds were burned.

In just five years, the 8,000 square miles of Iraqi marshes were reduced to no more than 700 square miles along a sliver of the border between Iraq and Iran. Most of the rebels and the Ma'adan were forced to relocate to cities. There they were at the mercy of Saddam's regime, which had absolute power over rations and therefore over their survival. Yet the marsh was losing its ability to sustain life. Fisheries suffered as spawning grounds in the marshes dwindled; with the loss of reeds to filter the water, more algal red tides swept over the region, killing more wildlife; thousands of water buffalo succumbed to pesticide poisoning, and the Ma'adan sold many others before being relocated into settlements.

Yet the devastation, as far-reaching as it was, has proved to be reversible.

The few people who had stayed in the marshes began breaching dams and tearing down embankments in late March 2003 even before the fall of Baghdad. Thus began the restoration of the marshes. In the past few years, the wetlands have begun to flourish. Iraqis continue to breach embankments: three breakthroughs on the Euphrates made in March of this year will help restore flow to the Ham-

mar Marsh. With foreign aid from around the world the marshes continue to grow.

Today, almost 3,000 square miles of the marshes are flooded. Half of that reflooded area seems to be in robust recovery; the other half still needs nursing. My colleagues and I have found encouraging numbers of endangered bird species—including Eurasian bittern, the Iraq babbler, pygmy cormorant, sacred ibis, and whiskered tern. The diversity of the wildlife improves daily.

One major problem, however, precludes the possibility of complete recovery: the loss of the seasonal freshwater pulses. Dams built in Turkey, Syria, and Iraq have, unfortunately, evened out the flow. Turkey began building its dams in the mountains of Kurdistan at the same time as the water

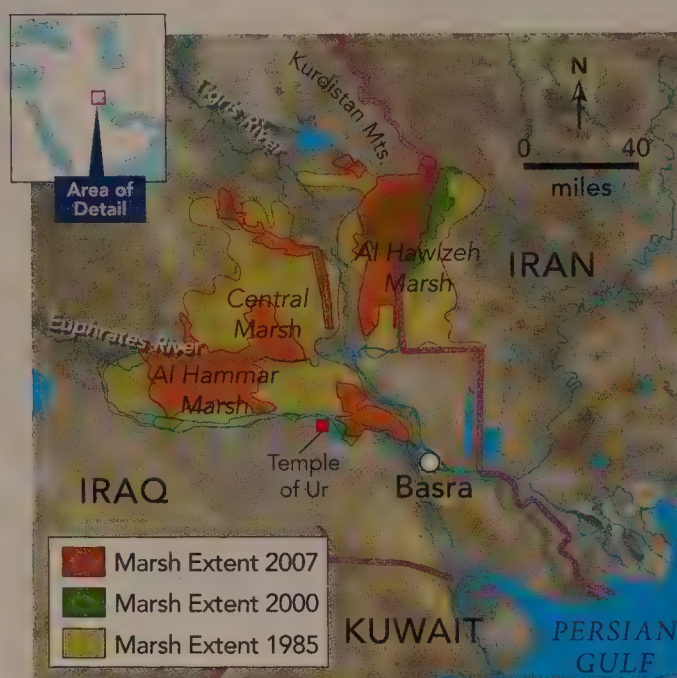
was being diverted to dry the marshes. The so-called South-eastern Anatolia Project, which is nearly finished, will comprise more than twenty-two dams and nineteen hydroelectric plants. The dams, albeit beneficial to the economy of Turkey, stopped the freshwater pulses that drove the marshes' biodiversity.

If the flow continues at its current, sluggish rate, some species that depend on the annual flushing—particularly fishes—may not survive. Engineers working on the marsh restoration have devised a plan to replicate the pulses. The plan would direct water from the dam reservoirs into the marshes during late winter, when agricultural demand is minimized. The water

would be held in the marshes into the spring season, regulated at the exit points and entrances to the marshes. Granted, such a scheme cannot truly replace the natural system, but the health of the marshes requires some kind of management, given that the dams upstream are likely to be in place for decades if not centuries to come.

The ultimate solution, of course, requires cooperation with upstream countries to coordinate seasonal releases of water for the benefit of the marshes. Some people, myself included, are hopeful. After all, five years ago most people shook their heads skeptically when they heard about the restoration of the Iraqi marshes; yet substantial progress has already been made.

The marshes are important not only for the health of the Gulf region, but also for their heritage as a rich cradle for both civilized and natural life. If more people and more countries step up to help Iraq, this rare ecosystem can be maintained for global benefit. All that is needed is political will. □



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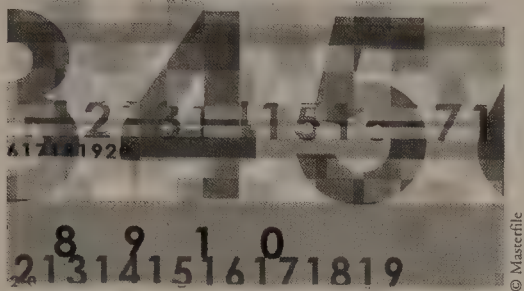
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Arthur T. Benjamin is Professor of Mathematics at Harvey Mudd College, where he has taught since 1989. He earned a Ph.D. in Mathematical Sciences from Johns Hopkins University. The Mathematical Association of America honored him with national awards for distinguished teaching in 1999 and 2000 and named him the George Pólya Lecturer for 2006–08.

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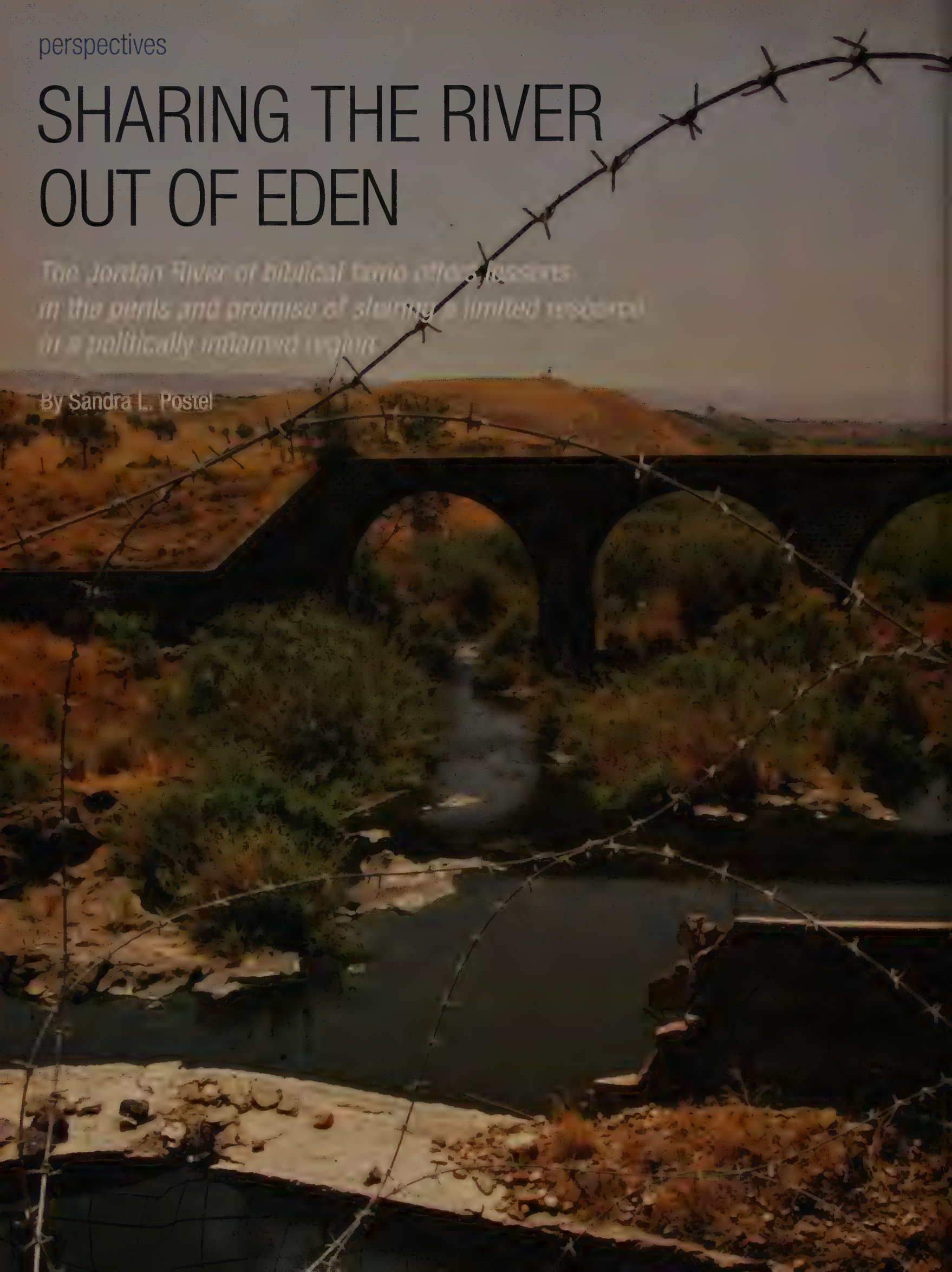
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perspectives

SHARING THE RIVER OUT OF EDEN

*The Jordan River of biblical fame offers lessons
in the perils and promise of sharing a limited resource
in a politically inflamed region.*

By Sandra L. Postel





When I first set eyes on the Jordan River, after a rainy winter in February 1992, I could scarcely believe that the thin ribbon of muddy liquid I saw winding its way southward could be the main prize in the contest for water in the Middle East. The Jordan is a small river. Its average annual flow is only 1.5 percent of what the Nile delivers to Egypt. By the time I encountered it, after several decades of its being dammed, diverted, and polluted, this legend of the biblical landscape, heralded in song as “deep and wide,” appeared dirty and spent.

Rarely has such a modest river been asked to do so much for so many. The Jordan and its tributaries serve five distinct political entities: Israel, Jordan, Lebanon, the Palestinians, and Syria. And unsurprisingly—in this most contentious and water-scarce of places—there is still no agreement about how the blue gold should be shared among all the parties. The Palestinians in the West Bank and Gaza are chronically short of water, and use a quarter as much per capita as do the neighboring Israelis. Inequitable access fans the flames of tension. Meanwhile, downstream lies the fabled Dead Sea—the lowest-lying and saltiest lake on Earth, and the Jordan’s final destination. But by the time the Jordan gets there, some 90 percent of its flow has already been diverted for domestic and agricultural uses upstream, so the river no longer sustains the sea. For the past quarter century, the lake level has been dropping about three feet a year; some warn that the Dead Sea could vanish by 2050.

As if those conditions weren’t dire enough, climatologists warn that global warming and its attendant increases in drought and evaporation may intensify the water shortages in the Middle East. At the same time, the projected rise in sea level may expose the coastal aquifers of Israel and Gaza to ruinous invasions of saltwater, rendering ever more wells unfit to supply drinking water.

In many ways the water predicament in the Middle East seems as intractable as the decades-long feuds over territory, Jerusalem, and refugees. But is it really so unyielding? Are there untapped solutions waiting to be deployed? And could an equitable resolution of water disputes perhaps become the wedge that opens new pathways to the grail of peaceful coexistence?

As with so much in the Middle East, a little geography tells a lot of the story [*see map on following page*]. The Jordan owes its flow to the confluence of three streams—the Hasbani River, which originates in Lebanon; the Dan River in northernmost Israel; and the Baniyas River, which emerges from Syria. The Jordan then flows south about twenty-five miles to the Sea of Galilee, Israel’s sole natural freshwater lake, which holds about a third of the nation’s renewable water supply. About six miles south of the Sea of Galilee, the Jordan is joined by its main tributary, the Yarmuk River, which originates in Syria and forms the Syrian-Jordanian border before

Barbed wire runs along the Jordan River, which forms the northern border between Israel and Jordan. The two countries have diverted huge amounts of water from the river for domestic and agricultural uses. They’ve pumped wastewater into the river, particularly the sixty-five-mile stretch from the Sea of Galilee downstream to the Dead Sea, shown in part here.

merging with the Jordan River in Israel. The Jordan then continues its journey southward to the Dead Sea.

A source of water crossing so many political boundaries, especially given the overheated politics and thirsty terrain of the Middle East, is a recipe for tension. Political leaders have routinely threatened war over the control of water. Golda Meir warned in 1960, when she was the Israeli foreign minister, that any attempt by Arab nations to divert the northern tributaries of the Jordan would be “an outright attack on one of Israel’s means of livelihood” and “a threat to peace.” In 1990 Jordan’s King Hussein declared that water was the only issue that could take him to war with Israel.

Ever since the creation of Israel in historic Palestine in 1948, the quest for water security among the parties of the Jordan basin has veered between unilateral action and cooperation. Recognizing the importance of water-sharing to the region’s stability, in 1953 the U.S. president, Dwight D. Eisenhower, appointed Eric Johnston, chair of the International Development Advisory Board, as special ambassador to the region to help negotiate a water-development plan. After two years, the so-called Johnston formula emerged. It allocated water according to the amount and location of irrigable land that could receive surface water by gravity—a sensible approach that placed water “needs” above water “rights.” By overlaying political boundaries on the map of irrigation potential, the Johnston plan arrived at a fair and technically feasible way of divvying up the water. Amazingly, the Johnston plan was acceptable to all parties at the time (though the Palestinians were not yet viewed as a distinct political entity). In the end, however, politics won out over rationality, and the plan was never formally ratified.

A spate of unilateral moves to capture and claim water followed, dramatically changing the hydrological landscape. In 1964 Israel began conveying the upper Jordan into its National Water Carrier, a system of canals and tunnels that supplies water to Tel Aviv and other coastal cities, as well as to desert agriculturalists in the Negev.



Attempts by the Arab nations to thwart Israel’s diversion plans and capture the Jordan’s headwaters for their own use led to skirmishes in the mid-1960s, including Israeli attacks on construction facilities at diversion sites in Syria.

It was Israel’s military victories during the Six-Day War of June 1967, however, that sealed its strategic hydrologic advantage. None other than Ariel Sharon, an Israeli commander in that war, noted that “the Six-Day War really started on the day Israel decided to act against the diversion of the Jordan.” Before the war, less than a tenth of the Jordan River watershed lay within Israel’s borders; by the war’s end, Israel had secured the vast majority of it. Israeli control extended to what had been Syria’s Golan Heights (which drain into the Sea of Galilee) and Baniyas River, as well as to critical groundwater aquifers under the West Bank. The latter territory, previously the possession of Jordan, now provides Israel with about a third of its water.

The three underground aquifers of the West Bank figure centrally in any effort to delineate and constitute a Palestinian state. The Yaqon-Taninim aquifer, the largest, runs along the foothills of the West Bank and flows westward across the Green Line (the Israeli boundary before the 1967 war) toward the Mediterranean Sea. Israel can now tap this groundwater on either side of the Green Line, but the aquifer’s main recharge zones lie under the West Bank.

During its occupation of the West Bank, Israel has prevented Palestinians from drilling wells for irrigation and has severely restricted Palestinian access to supplies. Journalist Fred Pearce reported in his 2006 book *When The Rivers Run Dry* that Palestinian families around Nablus spend between 20 and 40 percent of their income on water for drinking, cooking, and cleaning, while Israeli settlers nearby enjoy lawns and swimming pools.

This hydrologic inequity has worsened as a result of Israel’s construction of the controversial separation barrier that it began building in 2002. Israeli military officials say

As elusive as it may seem, **water security**—a sine qua non for lasting peace in the region—is within reach.

the approximately 425-mile stretch of wall and fencing, which in many areas extends considerably east of the Green Line, is necessary to protect Israeli cities and towns from Palestinian suicide bombers, and that security concerns alone determine the barrier's route. The Palestinians dispute this, viewing the barrier instead as a land-and-water grab. According to the Applied Research Institute of Jerusalem (ARIJ), a nonprofit organization dedicated to protecting the Palestinians' natural resources, the barrier could ultimately isolate Palestinian villages from 134 wells and 62 springs, as well as from some 260,000 acres (about 405 square miles) of productive farmland.

Of course, the Palestinians themselves also bear some responsibility for their water predicament. Years of infighting between the two principal factions, Fatah and Hamas, have distracted officials from the basic needs of their people, a problem compounded by a severe lack of financial and technical resources.

The water infrastructure is decaying, pollution is rampant, and the coastal aquifer is nearly destroyed. The water for 1.4 million Gazans comes from shallow groundwater that has long been overpumped—depleted faster than it can be replenished—and is already so contaminated by salt and pollutants that most of it does not meet the drinking-water standards of the World Health Organization.

As elusive as it may seem, water security for all—a sine qua non for lasting peace in the region—is within reach. Thanks to cooperation between scientists and citizen groups, advances in water-management technology, and agreements reached during peace talks in the early 1990s, there is a foundation on which to build lasting and more equitable water-sharing arrangements.

The Israeli-Jordanian peace treaty signed in October 1994, for instance, included water-sharing provisions that largely resolved the tensions between the two countries. Relying on the 1955 Johnston Plan to formulate his negotiating position, Jordan's lead water negotiator

limited Israel's share of the Yarmuk River, critically important to his country's water security.

Nothing nearly as conclusive emerged from the Israeli-Palestinian talks culminating in the 1993 and 1995 Oslo Accords, though some progress was made. Because Jordan had disengaged from the Israeli-occupied West Bank in 1988, it was up to the Palestinians, then represented by the Palestine Liberation Organization, or PLO, to negotiate their own water deal with Israel. In the Taba Agreement, or Oslo II, signed by Israel and the PLO in September 1995, Israel formally recognized for the first time that the Palestinians

have legitimate rights to West Bank groundwater—an important first step. How much water each side was entitled to, however, was left for the "final status" talks, which are yet to occur.

Coupled with further diplomatic initiatives to share water more equitably, a stronger push for straightforward measures to curb demand, expand supply, and use water more productively could generate enough water to satisfy the region's

needs. And few countries have more technical know-how in water management than Israel does.

Half a century ago, Israeli engineers developed highly efficient drip irrigation methods, and they've been perfecting them ever since. Drip systems deliver water directly to the roots of plants at low volumes through perforated tubing installed on or below the soil surface. Drip systems nearly eliminate wasteful evaporation and runoff, and compared with more conventional irrigation, they can double or triple the crop yield per unit of water. Israel now applies drip and other micro-irrigation methods on two-thirds of its cropland. With the help of Israeli engineers, Jordan, too, has adopted those methods, and now applies them on 55 percent of its farmlands.

Israel has also moved aggressively to treat, recycle, and reuse its urban wastewater. Seventy-three percent of treated sewage from Tel Aviv and other cities gets used a



Drip irrigation pipe in Netiv Ha'asara, Israel, rations out a precise sip of water to a plant. Israel and Jordan depend heavily on this technology for the efficient use of their limited water supply.

second time by farmers, in effect taking the “waste” out of wastewater. Recycled water makes up a fifth of Israel’s total supply, and its share is projected to grow.

Despite such gains in efficiency, irrigated agriculture still accounts for about two-thirds of Israel’s water use, yet it contributes only 2 percent to the nation’s gross domestic product. Israel imports a good deal of its wheat and other staple foods, but it still irrigates substantial tracts planted with fruits, vegetables, and other high-return crops. By reducing agricultural water subsidies and paring back irrigated farming, Israel could free up a substantial quantity

part, Palestinians publicly blame Israel’s water greediness. Yet behind the scenes, even during the worst of the second intifada, ministers from both sides quietly met and agreed not to damage each other’s water infrastructure.

Joined in destiny by the hydrological cycle, the people of the Jordan River basin know, whether consciously or subconsciously, that they must share the water of the basin and that cooperation can benefit them all. While traveling in the hills of Israel’s western Galilee region in 1992, I visited an Arab village of 7,000 people called Kfar

Even during the worst of the second intifada, ministers from both sides quietly met and agreed not to damage each other’s water infrastructure.

of water to share with its Palestinian neighbors—at little cost to its own economy.

Desalination—the removal of salt from seawater—could also yield sizable peace dividends. Although its costs are still high, they have fallen substantially in the past decade. In 2005, at Ashkelon, on the southern Mediterranean coast just north of Gaza, Israel opened the first of five planned desalination facilities. By a process called reverse osmosis, in which saltwater is filtered through a fine polymer membrane under high pressure to separate out the salts, the facility can produce 100 million cubic meters of desalinated water per year. That capacity makes the Ashkelon plant the largest reverse-osmosis seawater desalination plant in the world.

By 2010, Israel expects to be desalinating a total of 315 million cubic meters of seawater per year, nearly equal to its current use of freshwater from the West Bank aquifers. If Israel were to substitute desalinated seawater for West Bank groundwater, Palestinians there could double their current water use while easing up on the overpumping of the aquifers.

Unfortunately, no such deal is in the cards. Israeli officials have instead proposed that the United States help fund the construction of a desalination plant on the Mediterranean coast at Caesarea. From there, they suggest, the desalinated water could be transferred to the West Bank for use by the Palestinians. Under that proposal, Israel would retain its control of West Bank groundwater, and the Palestinians would get high-priced desalinated seawater from Israeli territory—hardly a recipe for Palestinian water security.

Why is Israel pushing for this approach? Driven by a deep mistrust of Palestinian motives, Israel feels a need to retain control over the region’s water supplies. For their

Manda. The sewage from the village was managed by a neighboring Jewish community, Yodfat. A series of small reservoirs stored Kfar Manda’s wastewater and treated it biologically; it then became a source for drip irrigation in Yodfat’s cotton fields. The Arab villagers got an inexpensive way of handling their sewage, which might otherwise have flowed untreated into their surroundings. And the Yodfat farmers got a reliable and less costly source of water for irrigation—water that carried enough nitrogen and phosphorus to markedly cut their fertilizer costs. By bridging the ethnic and religious divides, the two communities reaped benefits that neither would have achieved without the other.

With similar methods and goals in mind, EcoPeace/Friends of the Earth Middle East (FoEME), a private organization of Arab and Israeli environmentalists, initiated the “Good Water Neighbors” project in 2001. It aims to organize joint water-management projects between cross-border communities in Israel, Jordan, and the Palestinian territories. Seventeen communities are participating so far, each one working with its partner across their common border on the water problems they share. A mayors’ network has been formed to give residents a voice on such larger issues as the health of the Jordan River, the demise of the Dead Sea, and the implications of the separation wall under construction in the West Bank.

Along with the drip irrigation lines and desalination units that increasingly dot the landscape of the Jordan River basin, technical and civilian cooperation has persisted throughout years of violence and political stalemate. That spirit of cooperation stands ready to be harnessed and augmented to build a secure water future for all in the region. If it is not, political leaders will have squandered far more than water. □

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BOOKSHELF

By Laurence A. Marschall



Industrial plants in River Rouge, Michigan, on the banks of the Detroit River

The Great Lakes Water Wars
by Peter Annin
Island Press; \$25.95

When I was growing up in Buffalo, New York, the Great Lakes seemed to me to be a limitless source of water and of wealth. Ah, innocent youth! By the late 1950s the "Sweet Water Seas" to the west of town were turning foul, the freighters were docking less frequently, and the steel and auto plants were starting to close. Buffalonians like me, and our counterparts in other soon-to-be "rust belt" cities—Gary, Detroit, Cleveland, Erie—were beginning to lose their feeling of security and, in its place, to develop a new environmental anxiety.

In the decades since, state and local governments have learned to deal more effectively with sewage and industrial waste—"aided" in part by the continuing loss of heavy industry to other countries. The feeder rivers no longer catch fire, as the Cuyahoga did in downtown Cleveland in 1969, and pollution in the lakes has been reduced. But the 40 million people in the region who depend on Great Lakes water are

still on edge, understandably worried about what the future will bring. Any threat to the integrity of Great Lakes water touches a raw nerve.

The greatest fear of the Great Lakes' terrestrial neighbors is that their waters will be stolen outright, diverted to irrigate golf courses in Las Vegas, fill swimming pools in Phoenix, and supply condos in San Diego. That's not sheer paranoia. The driest parts of the nation are also the fastest-growing. And over the years a number of elaborate proposals have been floated to get the Great Lakes flowing southwest.

One project of the 1960s, undoubtedly named the Great Recycling And Northern Development Canal so to create its grandiose acronym, called for freshwater to be pumped from the Hudson Bay watershed into Lake Huron, then through a series of canals to Montana and Wyoming, and eventually into the Colorado River. From there it would be distributed to nearby urban centers and agribusinesses. Public condemnation, and a price tag in the hundreds of billions of dollars, quickly squelched the idea, but it has never completely died.

Another flurry of worry erupted in

the 1970s over the decline of the Ogallala aquifer in the central United States, which supplies water to the High Plains. At the bidding of concerned plains-state legislators, the U.S. Army Corps of Engineers investigated the feasibility of transporting water to Kansas, Nebraska, and Colorado from what the Corps study euphemistically called “adjacent areas,” sparking another heated reaction from the Great Lakes states.

Those episodes and others confirmed what was already pretty obvious: to the people in the eight states and two Canadian provinces that border the Great Lakes, the smallest diversion of water outside the watershed is to be vigilantly avoided. Even a trickle, they fear, would eventually open the floodgates of diversion and suck the lakes dry. Having seen the damage wreaked by mismanagement, they are not about to submit their lakes to the same fate as that of Russia’s great Aral Sea [see “Blue Planet Blues,” by Eleanor J. Sterling on page 29].

Peter Annin, a former correspondent for *Newsweek*, describes the environmental and legislative turmoil that engulfs the Great Lakes today. Since the 1980s, the states and provinces bordering the Great Lakes have enacted a series of protocols and agreements on water management that have met with varying degrees of success in preventing unsound diversions. But water-management difficulties stem not merely from outside threats, but also from the challenge of defining and reconciling the often clashing interests of multiple governments, residents, and industrial communities in the waters they each claim but must share. The Great Lakes drainage does not respect political boundaries.

Case in point: Waukesha, Wisconsin, a western neighbor and now suburb of Milwaukee, wants to replace its current system of wells with a connection to the bigger city’s water mains, which draw from Lake Michigan. The proposal looks like a straightforward matter of plumbing. Yet Waukesha’s effluent goes into the nearby Fox River, which

drains into the Mississippi—not into the Great Lakes—so even the simple joining of pipes represents a diversion with international repercussions.

Does that seem far-fetched? Shouldn’t tap water for a bedroom community remain a matter for local politicians, particularly in a region as rich in water as the Great Lakes? Perhaps, but Waukesha and the other cases Annin recounts are emblematic of one of the central issues of our century, as population growth, expanding economies, and limited resources bring the water wars to everyone’s doorstep.

Dry: Life Without Water
edited by Ehsan Masood
and Daniel Schaffer
Harvard University Press; \$29.95

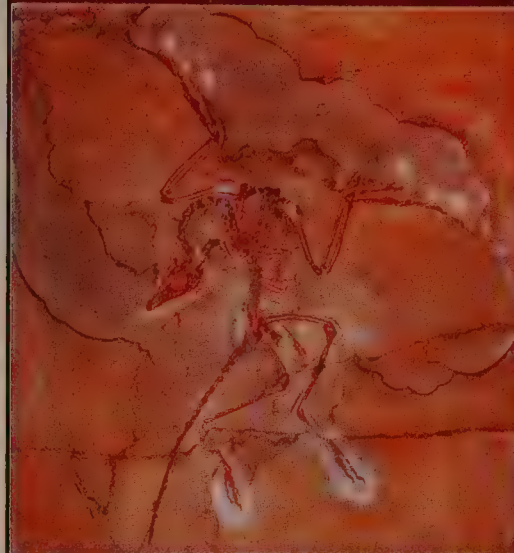
Most of us who read this magazine (or write for it, for that matter) scarcely have to think about where our next glass of water is coming from: it’s just a matter of turning a tap. Yet for roughly a billion people, dwellers in the arid and semi-arid regions that make up 40 percent of the Earth’s landmasses, every drop is a serious concern. Because water is so critical to economic development, arid lands are among the poorest places on Earth—with the notable exceptions of Las Vegas, Dubai, and other highly subsidized anomalies of the developed world.

Desert lands, not surprisingly, are also among the most threatened ecologically, because the delicate balance of their scanty resources is so readily upset. *Dry*, a collection of short vignettes about life in some of the planet’s most arid places, written by scientists and science journalists and illustrated with vivid photography, describes a recent attempt to address the economic and environmental problems of those lands. The chapters report on a variety of practices, identified by a multiyear scientific program, that both utilize and conserve the water resources and biodiversity of the developing world.

Some of the practices are straight-

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forward applications of modern technology to traditional settings. In the northwestern provinces of China, for instance, rural villages have long collected the seasonal rains of summer and autumn in communal "rain cellars" for use during the rest of the year. But traditionally the cellar walls have been made of raw clay, so by the end of the dry season the remaining water is often muddy and contaminated. In recent years a project known as "Mother's Water Cellars" has financed 80,000 cement-lined cisterns in those rural areas, providing longer-term, healthier storage of a scarce resource. "Now we can wash our faces at any time we want," said one satisfied farmer.

Even drier conditions call for higher-tech solutions. Villages in Chile's Atacama Desert, where years can pass without significant rainfall, have survived for the most part on water trucked in from far away. But in the late 1980s Chilean scientists began to experiment with large nets made of polypropylene mesh, which catch droplets of fog and channel them into plastic pipes for distribution [see "Hydro Tech," on pages 54–55]. A square meter of net can catch perhaps ten liters of water a day; a system of such fog catchers can easily provide water for a village of several hundred people at little operating cost. A trial project in the 1990s met with great initial success.

Unfortunately, local residents and government officials let the system fall into disrepair. By 2000, villages that had been getting reliable water from the nets were back to trucking it in. That setback may be nothing more than a minor stumble on the path to self-sufficiency. Perhaps given more durable webbing, and economic incentives for locals to maintain the nets and piping, Chile's fog nets could become a permanent source of water in the years to come.

Many sustainable water-saving tactics recognized in *Dry* are traditional systems that have been around for centuries. In the Jebel Akhdar mountains of Oman, the parched hillsides

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support a flourishing rose-growing industry, irrigated by a complex system of tunnels and covered, stone-lined channels that date back thousands of years. And in the date-producing Ziz Valley in Morocco's High Atlas mountains, women pass along traditional knowledge about how best to irrigate fields, how to select the best seeds for planting, and what times are best to plant and harvest for greatest yields.

What works in the arid world, according to the reports in *Dry*—what seems to keep traditional societies in parched lands both healthy and productive at a modest level—is a combination of ancient methods and appropriate new technologies. None of the places highlighted in the book seem destined to become the next Las Vegas or Dubai—but who would wish for that?

***Sacred Sea: A Journey
to Lake Baikal***

by Peter Thomson

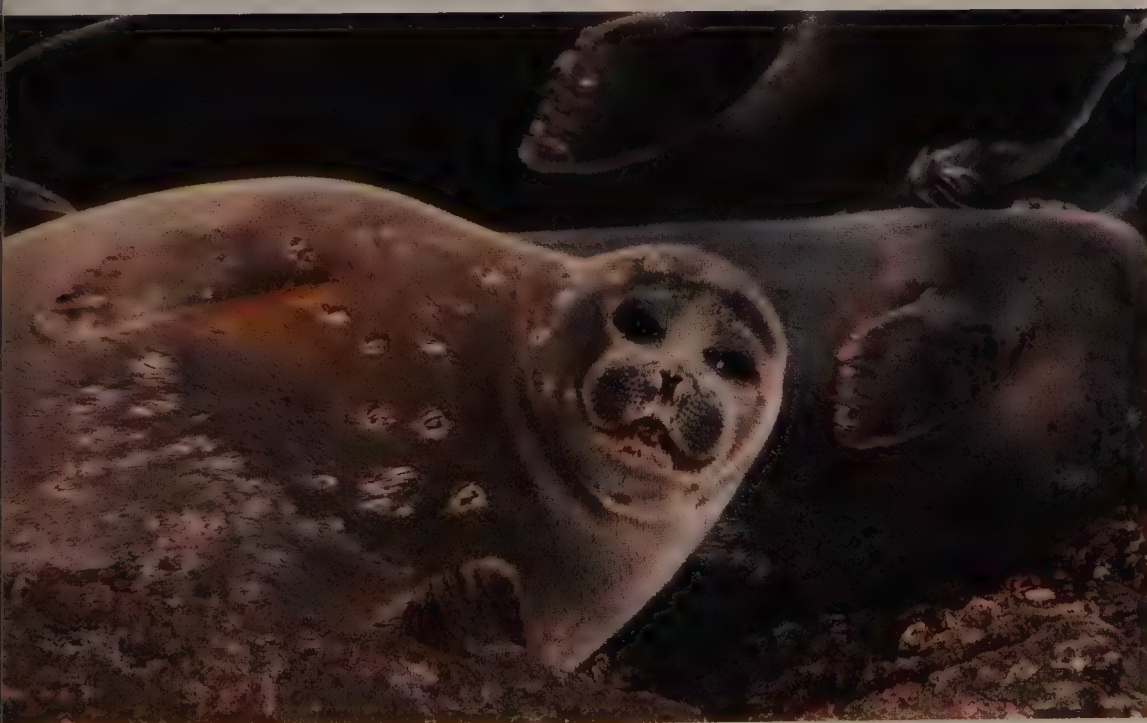
Oxford University Press; \$29.95

Siberia's Lake Baikal, like so much that is Russian, is riddled with contradictions. Halfway between the Urals and the Pacific, the lake is so remote that few Russians have seen its shores, even though they regard it with a mystic

reverence far surpassing the American devotion to Yellowstone or the Grand Canyon. As for non-Russians, few foreigners appreciate Baikal's uniqueness—if they know of its existence at all. Yet Baikal surely ranks among the greatest natural wonders of the world. Its crescent-shaped basin, though out-ranked in surface area by Lake Superior and a few other bodies of water, is far deeper and far greater in capacity than any other lake: Baikal, by itself, holds a fifth all the freshwater on Earth.

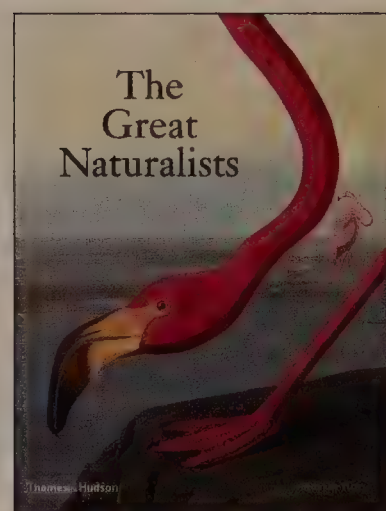
Formed 25 million years ago, the “blue eye of Siberia” is thousands of times older than the Great Lakes. And because Baikal is so isolated, a kind of watery analogue to Australia or New Zealand, its aquatic ecosystem has evolved in unique directions. Among more than twenty-five species of fish that live exclusively in the lake, the most abundant are weird creatures called golomyankas, whose bodies are translucent. No more than a foot long, they swim with their heads up, like seahorses, and bear their young live. The lake is even home to a singular species of mammal, the nerpa, the world's only freshwater seal, which can spend as long as three-quarters of an hour in the frigid depths before coming up for air.

What makes Baikal even more remarkable is the purity of its water. No



Nerpa, freshwater seals, lounge on Lake Baikal's shore.

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cities about the lake, only a few towns with low-five-figure populations, and the only roads of note, along with the Trans-Siberian Railway line, lie along the far southern end. Scarcely 80,000 people make their homes along the 1,200 miles of shoreline, most in tiny settlements accessible only by boat. The only major sources of pollution come from a pulp and paper mill on the southern shore, and from effluent dumped into inflowing rivers by cities and farms in Siberia and Mongolia. At first glance, the world's greatest lake seems an astonishingly pristine and untroubled place.

Peter Thomson, the founding editor and producer of National Public Radio's ecology news show *Living On Earth*, made his first trip to Baikal in 2000. In part, his goal was to find out for himself whether the Edenic character of Baikal was fact or myth. His account of that journey is a hybrid of

environmental reporting and personal travelogue, the product of a six-month respite Thomson took after his marriage ended and his mother died. Casual readers will enjoy his accounts of meandering across the Pacific on a container ship with his younger brother, camping among Siberian aspens, and feasting on reindeer meat under the northern lights. But the focal points of his narrative are Thomson's vivid encounters with activists, scientists, and residents of the Baikal region. Just how pristine was the lake, he asked them, and how likely was it to remain that way?

The answer, it turns out, is as murky as Baikal's waters are clear. Baikalian optimists view the lake as a self-cleaning ecosystem, constantly filtered by tiny shrimplike crustaceans called *Epischura baicalensis*. According to one local scientist, those zooplankton, endemic to Baikal, "consume every molecule of any substance that comes

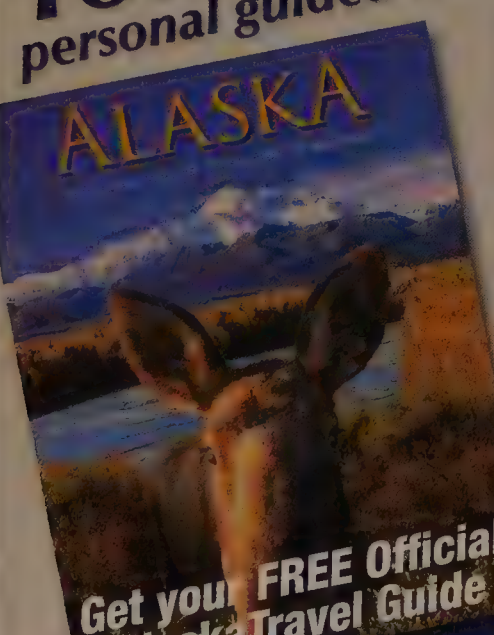
to its waters," making it impossible to overload the lake with pollutants. Others, equally eloquent, see glowering clouds on the horizon. They reasonably fear increased development, swelling amounts of effluent from distant cities, insufficient preservation of the national reserves and parklands along Baikal's shore, and the disruption of Baikal's ecosystem by global warming.

Whether the optimists or the pessimists are right, they do agree on one thing: the choices made and actions taken in the coming century will determine whether or not Baikal will remain one of Mother Russia's most timeless treasures.

LAURENCE A. MARSCHALL, author of The Supernova Story, is W.K.T. Salm Professor of Physics at Gettysburg College in Pennsylvania and director of Project CLEA, which produces widely used simulation software for education in astronomy.

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MARYLAND

17. CHESAPEAKE BAY MARITIME MUSEUM

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18. CHOOSE CALVERT COUNTY

Less than an hour from D.C. discover Chesapeake Bay history. Hunt along sandy beaches for over 600 fossil species at the 15-million-year-old Calvert Cliffs.

19. DORCHESTER COUNTY

Home to world-renowned Blackwater National Wildlife Refuge; explore the heart of Chesapeake Country on Maryland's Eastern Shore.

20. FREDERICK COUNTY

Maryland's Crossroads of History. Antiques, battlefields, covered bridges, parks, wineries and more close to Gettysburg and DC.

21. KENT COUNTY

A scenic peninsula on the Chesapeake Bay, offering fishing, boating, kayaking, small beaches, great shopping, and museums.

22. MARYLAND VACATIONS

Beaches, mountains, big cities, small towns. Maryland has so many things to do, so close together.

23. MONTGOMERY COUNTY

Experience transportation history along the C&O Canal and the National Capital Trolley Museum. So many things to do.

24. ST. MARY'S COUNTY

Potomac River lighthouses, Chesapeake Bay seafood, and maritime history. Quaint towns, scenic byways, and tidewater trails. Cozy inns, waterside dining and fantastic festivals.

25. TALBOT COUNTY

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26. WORCESTER COUNTY

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At the Museum

AMERICAN MUSEUM OF NATURAL HISTORY



www.amnh.org



Immerse Yourself Water: $H_2O = Life$

Anyone who's ever watched kids running through sprinklers or splashing around with toys in a tub knows the mesmerizing hold water has on children. So when the American Museum of Natural History set about designing the exhibition *Water: $H_2O = Life$* , awareness of this fascination helped transform compelling yet complex science into a family affair.

From hands-on water works to interactive computer stations to evocative walk-throughs, visitors young and old are treated to a host of viscerally engaging experiences as they explore a virtual "flood" of information about the essential nature of water and the current and future water-related challenges facing the world.

"This eye-opening exhibition brings visitors closer to water in more ways than they ever imagined possible and hopefully leaves them with a deep sense of responsibility towards conservation of this remarkable ingredient for life," said Eleanor Sterling, Director of the Museum's Center for Biodiversity and Conservation and curator of *Water*, which opened this month.

Setting an interactive tone from the start is a veil of mist through which visitors pass at the entrance, a reminder of the abundance of a substance that covers more than two-thirds of the Earth's surface. Striking a paradoxical note, the next display evokes potable water's rarity—less than 1 percent of the planet's water is readily available for human

use—with water droplets falling from the ceiling to a table so that people can run their hands beneath the drops.

And this is just the beginning.

An interactive feature on the three states of water allows visitors to touch water as a liquid, ice, or vapor, while a display nearby explains the water cycle, the series of stages by which our finite water supply endlessly moves from underground and bodies of water into the atmosphere and back again. (Part of the inspiration for this exhibition was the finding in a 2006 AMNH survey that 41 percent of U.S. residents could not name a single component of the water cycle, such as evaporation or rain.)

Other hands-on exhibits permit visitors to block and release the flow of water, akin to building and removing a dam, to study the respective effects on a river bed; pump water from an artesian well to mark the decrease of water pressure in another well drawing from the same underground source; and lift a container filled with water to get a sense of its weight and the literal burden that carrying water still is for many populations around the globe. This last is accompanied by a beautiful and telling display of water receptacles from ancient vessels to plastic cans used today. Of related and special interest to children, a working tabletop model of a PlayPump water system shows how children playing on a merry-go-round are actually pumping water from the ground into a tank, an ingenious method that has

greatly increased access to clean drinking water in rural communities of Africa.

A microscope station allows visitors to see the world of microbes in a single drop of untreated water, while what is seen through the eyepiece is projected on a large screen. One drop of water from a lake, river, or ocean can contain thousands of tiny organisms, like algae, protozoans, bacteria and viruses. (Most are harmless—fewer than 1 percent of bacteria cause disease.)

Throughout the exhibition, live animals, models, fossils, and taxidermy specimens embody the varied and surprising adaptations animals have evolved to survive in extremes of wet and arid conditions. Visitors will learn, for example, how wood frogs freeze to hibernate in winter; Pompeii worms survive plumes of near-boiling water on the Pacific floor; and albatrosses, which spend months flying or floating on the ocean, drink water too salty for most birds and land animals. A vivarium of live mudskippers offers a look at curious “fin-footed” fish that can live for extended periods out of water. Beneath a model polar bear on a faux ice floe, younger children are drawn to a matching game in which blocks, when

properly aligned, trigger videos about life where ice is the norm.

Also making dry statistics real is an interactive quiz testing visitors’ “H₂O IQ” with such questions as how much water it takes to make a T-shirt or a hamburger, an exercise that’s fun, informative, and surprising. In fact, anyone visiting *Water* isn’t likely to soon forget that nearly 900 gallons of water are needed to produce just 2.2 pounds of rice!



Early in the exhibition, visitors pass through a re-creation of a water-sculpted slot canyon, a graphic portrayal of the power of water to shape the contours of the planet. The human effect on the landscape is starkly represented near the end of the exhibition with a haunting, life-size, walk-through

diorama of Mono Lake and its once-submerged tufa (or limestone) towers, exposed when the water level dropped some 45 feet over decades of diverting fresh water to Los Angeles. On the brink of collapse in the late 1970s, Mono Lake’s ecosystem is now on the mend through efforts by the state of California, spurred on by graduate students and concerned citizens—a message of hope that human action can also act as a healing force.

Science on a Sphere: The “Globe” Theater

If you’ve ever longed to see Earth from space, now is your chance—with *Science on a Sphere*, a spectacular feature at the heart of the new exhibition *Water: H₂O = Life*.

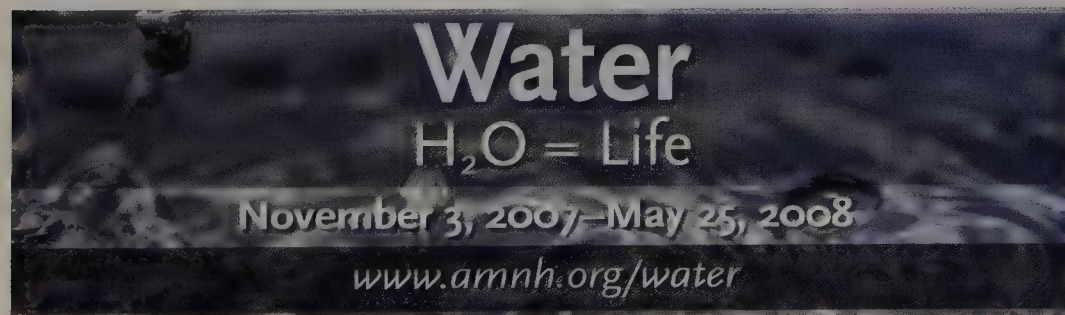
In this exhibit, a six-foot-diameter globe hangs suspended as if floating, depicting in living color how water defines and drives the planet. The stunningly realistic effect, showing shifting conditions on a seemingly rotating orb, is achieved by four full-motion video projectors, placed at the four corners of the room and controlled by a central computer, beaming images derived from data gathered by NASA satellites and other scientific sources.

In one sequence, Earth’s surface, of which nearly 71 percent is covered in water, is contrasted with frozen Mars and hot, dry Venus, as well as with the Moon, which is waterless. Through time-lapse projections, Earth’s water cycle springs to life as tropical areas turn green, then brown; ocean currents move warm water from the tropics to polar regions and cold polar water toward the tropics; and snow cover comes and goes.

Even deep beneath Earth’s surface, water in minerals that make up Earth’s mantle is seen to be on the move, making possible the movement of continents, and causing volcanoes, earthquakes, and the rise of new mountain ranges. *Science on a Sphere* presents patterns of water and population distribution, and graphically shows how little water is suitable for fresh human use.

Science on a Sphere is an amazing educational tool for both kids and adults. Dynamic and realistic visual interpretations of actual scientific data illuminate Earth’s systems and ask us to think about how and why Earth is changing before our very eyes.

Science on a Sphere (SOS) is the creation of the Global Systems Division, Earth System Research Laboratory of the National Oceanic and Atmospheric Administration (NOAA). Support for SOS is provided by the National Science Foundation and NOAA with technical assistance from the Scientific Visualization Studio at NASA Goddard Space Flight Center.



Water: H₂O = Life is organized by the American Museum of Natural History, New York (www.amnh.org), and Science Museum of Minnesota (www.smm.org) in collaboration with Great Lakes Science Center, Cleveland; The Field Museum, Chicago; Instituto Sangari, São Paulo, Brazil; National Museum of Australia, Canberra; Royal Ontario Museum, Toronto, Canada; San Diego Natural History Museum; and Singapore Science Centre with PUB Singapore.

The American Museum of Natural History gratefully acknowledges the TAMARIND FOUNDATION for its leadership support of *Water: H₂O = Life*, and the Johns Hopkins Center for a Livable Future for its assistance.

Water: H₂O = Life is supported by a generous grant from the NATIONAL SCIENCE FOUNDATION.

Exclusive corporate sponsorship for *Water: H₂O = Life* is provided by JP MORGAN.

The Museum also extends its gratitude to the Panta Rhea Foundation, Park Foundation, and Wege Foundation for their support of the exhibition’s educational programming and materials.

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY 

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EXHIBITIONS

The Butterfly Conservatory

Through May 26, 2008

Mingle with up to 500 live, free-flying tropical butterflies in an enclosed habitat.

Learn about the butterfly life cycle, defense mechanisms, evolution, and conservation.

Brilliant color photographs capture the dazzling invertebrate life that flourishes on coral reefs.

Beyond

Through April 6, 2008

Exquisite images from unmanned space probes take

tools in the search for planets around stars other than our own Sun.

This exhibit, part of the education and public outreach efforts of NASA's Navigator Program, was made possible through a grant from NASA's Michelson Science Center at the California Institute of Technology.

GLOBAL WEEKENDS

Buddhist Ritual Song and Dance from Korea

Friday, 11/2, 7:00 p.m.

The Young San Preservation Group performs.

City That Drinks the Mountain Sky

Sunday, 11/18, 2:00 p.m.

Arm-of-the-Sea Theater tells the story of New York City's water supply through puppetry, poetry, and music.

Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, the New York City Council, and the New York City Department of Cultural Affairs. Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

LECTURES

No Way Home

Tuesday, 11/13, 7:00 p.m.

David S. Wilcove explores animal migration and



COURTESY DAVID S. WILCOVE

the dangers our current environment presents for the successful growth of species that migrate.

Adventures in the Global Kitchen: An Evening with Jay McNerney

Tuesday, 11/13, 7:00 p.m.

Jay McNerney will share stories of viniculture and offer tastings of favorite wines. A book signing follows.

Life in the Valley of Death

Tuesday, 11/20, 7:00 p.m.

Alan Rabinowitz discusses the largest tiger reserve in Myanmar.

Our 100-Million-Year-Old Ecosystem

Wednesday, 11/28, 6:30 p.m.

Michael Novacek will discuss Earth's 100-million-year-old evolutionary history and ways to protect its future.

FILM

Margaret Mead Film & Video Festival

Friday–Sunday, 11/9–11



ROSE CENTER FOR EARTH AND SPACE

Sets at 6:00 and 7:30 p.m.

Friday, 11/2

Visit www.amnh.org for lineup.



H. DAVIES/AMNH

These pupae will soon be butterflies.

Mythic Creatures: Dragons, Unicorns, and Mermaids

Through January 6, 2008

Mythic Creatures traces the origins of legendary beings of land, sea, and air. Cultural artifacts bring to light surprising similarities—and differences—in the ways peoples around the world have depicted these beings, and fossil specimens suggest a physical basis for the many forms they have taken.

Mythic Creatures: Dragons, Unicorns, and Mermaids is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with The Field Museum, Chicago; Canadian Museum of Civilization, Gatineau; Australian National Maritime Museum, Sydney; and Fernbank Museum of Natural History, Atlanta. *Mythic Creatures* is proudly supported by MetLife Foundation.

Undersea Oasis: Coral Reef Communities

Through January 13, 2008

visitors on a journey through the alien and varied terrain of our planetary neighbors.

The presentation of both *Undersea Oasis* and *Beyond* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Unknown Audubons: Mammals of North America

Through January 6, 2008

The stately Audubon Gallery showcases gorgeously detailed depictions of North American mammals by John James Audubon, best known for his bird paintings.

Major funding for this exhibition has been provided by the Lila Wallace-Reader's Digest Endowment Fund.

Exoplanets and the Search for Life

Through March 2008

Two striking astronomical instruments demonstrate the need for extremely specialized

Celebrate the 31st anniversary of the Margaret Mead Film & Video Festival with the best of international documentary with screenings, discussions, and panels.

www.amnh.org/mead

WORKSHOPS

Introduction to Human Origins

Three Thursdays, 11/1–15

6:30–8:00 p.m.

Use hominid casts to learn about morphological analysis and how scientists reconstruct behavior from fossil evidence.

FAMILY AND

CHILDREN'S PROGRAMS

Field Trip to the Moon

Every Wednesday, 10:30 a.m.

Guided by a live presenter, this new program flies visitors to the Moon in the Hayden Planetarium.

Flint-knapping Demonstration

Saturday, 11/17, 12:30–1:30 p.m.

With anthropologist John Shea.

Dr. Nebula's Laboratory:

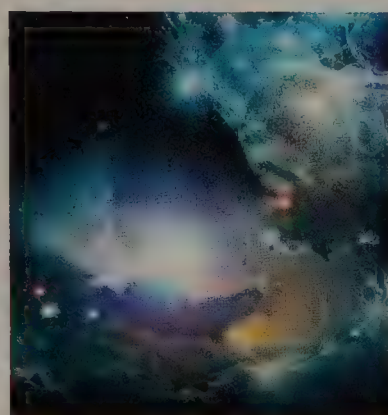
Life with Lucy

Saturday, 11/17, 2:00–3:00 p.m.

(Recommended for families with children ages 4 and up)

Help Dr. Nebula's apprentice, Scooter, travel back in time to meet our hominid ancestors.

This program is made possible, in part, by an anonymous donor.



Artist's conception of a primordial quasar

NASA/ESA/ESO/VOLFRAM FREUDLING ET AL. (STECF)

Public programs are made possible, in part, by the Rita and Frits Markus Fund for Public Understanding of Science.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe

Why the Universe Looks the Way It Does

Tuesday, 11/6, 6:30 p.m.

Celestial Highlights

Here Comes Mars!

Tuesday, 11/27, 6:30 p.m.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions

Journey into deep space to explore the hypersonic impacts that drive the formation of our universe. Narrated by Robert Redford.

Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum. Made possible through the generous support of CIT. *Cosmic Collisions* was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

Sonic Vision

Fridays and Saturdays, 7:30 and 8:30 p.m.

Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamscape.

Presented in association with MTV2 and in collaboration with renowned artist Moby.

IMAX MOVIES

Dinosaurs Alive!

On location with AMNH scientists past and present, this stunning new large-format film uses scientifically accurate, computer-generated images to bring to life these intriguing animals, from the earliest dinosaurs of the Triassic Period to the creatures of the Cretaceous.

LATE NIGHT DANCE PARTY One Step Beyond

Friday, 11/30, 9:00 p.m.–1:00 a.m.

This monthly party in the Rose Center features the biggest names in techno, electronica, and jazz. Food and drink keep the party going.

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., and Saturday, 10:00 a.m.–4:00 p.m., or visit www.amnh.org. A service charge may apply. All programs are subject to change.

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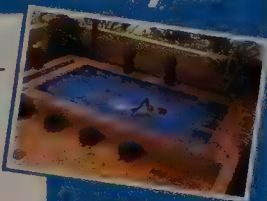


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THE SKY IN NOVEMBER

By Joe Rao

Mercury becomes easy to see with the naked eye in the morning sky early this month; for northern observers, this apparition is its most favorable one of the year. The planet starts the month rising more than an hour before sunup, far below and to the left of Venus, and shining a bit brighter than the nearby first-magnitude star Spica. Mercury remains within four degrees to the left of Spica for the first week of the month. From the 1st through the 11th the planet's brightness increases four-fold, helping to make the second week of the month Mercury's finest show. It rises an hour and a half before sunrise and several minutes before the onset of morning twilight, in a totally dark sky. On the 7th a lovely waning crescent Moon appears to ride well above and to the right of Mercury and Spica. The following morning Mercury approaches its greatest western elongation, nineteen degrees from the Sun. Thereafter it slowly turns back toward the Sun, but it should remain visible low in the east-southeast about forty-five minutes before sunrise until the 22nd.

Venus dazzles in the predawn morning sky, rising almost four hours before sunrise at the start of the month. It loses only about ten minutes to the Sun by month's end, and is well up in the southeast sky by sunrise all month. Viewed through a telescope, Venus starts the month resembling a half Moon (a phase called dichotomy), but after a week it gradually becomes more gibbous. A crescent Moon lies to the right of Venus on the morning of the 5th.

Mars becomes a noteworthy evening object this month, advancing its rising time from about three and a half hours after sunset when the month begins to about two hours by month's end. It reaches opposition this year on Christmas Eve, and as that event draws near, the planet's brilliance almost doubles, from magnitude -0.6 to -1.3 . By late in the month, many holiday shoppers who cast a casual glance skyward will wonder about the identity of that lus-

trous, pumpkin-hued "star" low in the east-northeast sky.

Jupiter bids evening skywatchers a fond, albeit slow, adieu. At the start of the month it lies low in the southwest during the chilly dusk, setting a little more than two hours after sundown. By the 20th it sets before the end of evening twilight.

Saturn begins the month seven degrees east of the bluish star Regulus, in the constellation Leo, the lion, and moves a degree farther east of the star by month's end. The planet rises more than five hours before sunrise on the 1st, at about local midnight by the 20th, and before 11:30 P.M. by the 30th. By then the planet is high in the south-southeast as morning twilight begins. At magnitude $+0.8$, Saturn outshines Regulus (magnitude $+1.4$), but the planet is at its faintest since 1997.

The **Moon** is at last quarter on the 1st at 5:18 P.M. (eastern daylight time) and wanes to new on the 9th at 6:03 P.M. Our satellite waxes to first quarter on the 17th at 5:32 P.M. and to full on the 24th at 9:30 A.M.

An **occultation of Regulus**, the brightest star in Leo, takes place before sunrise on the morning of the 3rd, when a fat waning crescent Moon passes in front of the star. The event is visible chiefly in the southern United States, Mexico, and the Caribbean; over parts of Georgia, Florida, and Alabama it takes place during morning twilight or right after sunup. The star disappears behind the Moon's bright limb, then dramatically reappears about an hour later from behind the Moon's dark limb. Visit tinyurl.com/274cer for a list of viewing times for more than a hundred cities.

Standard time returns on Sunday the 4th. Set your clocks back one hour.

Unless otherwise noted, all times are eastern standard time.



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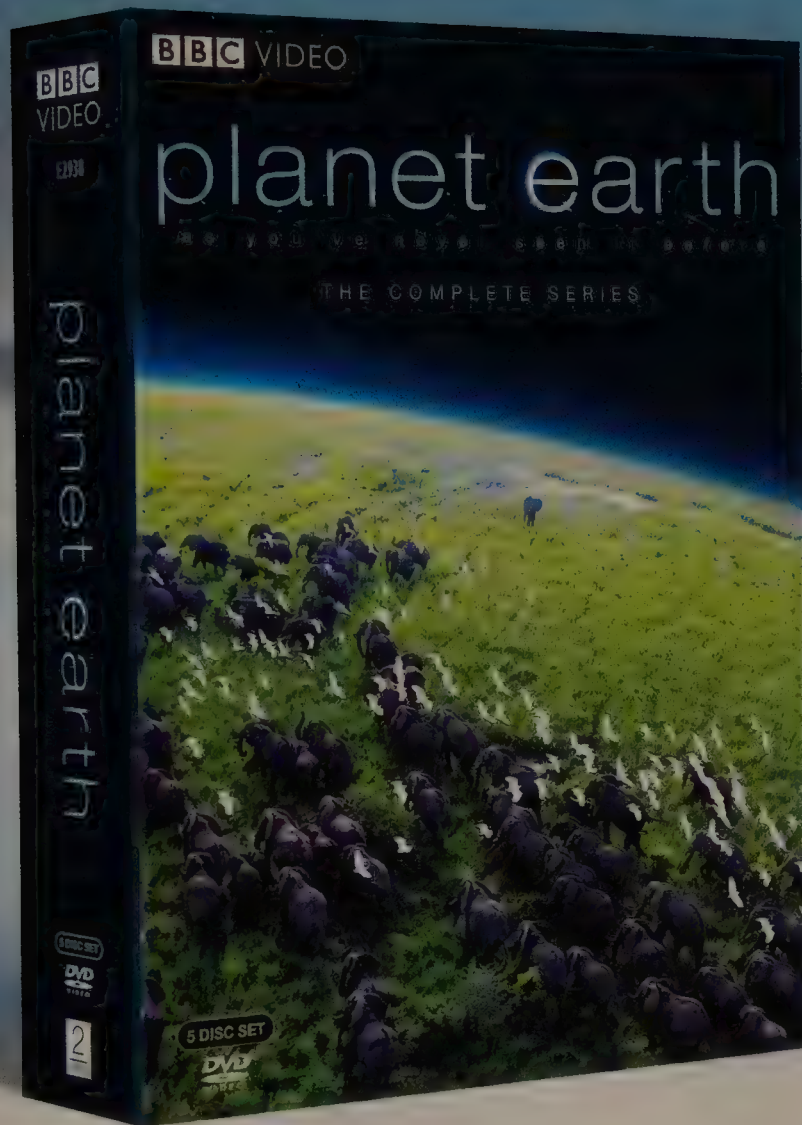


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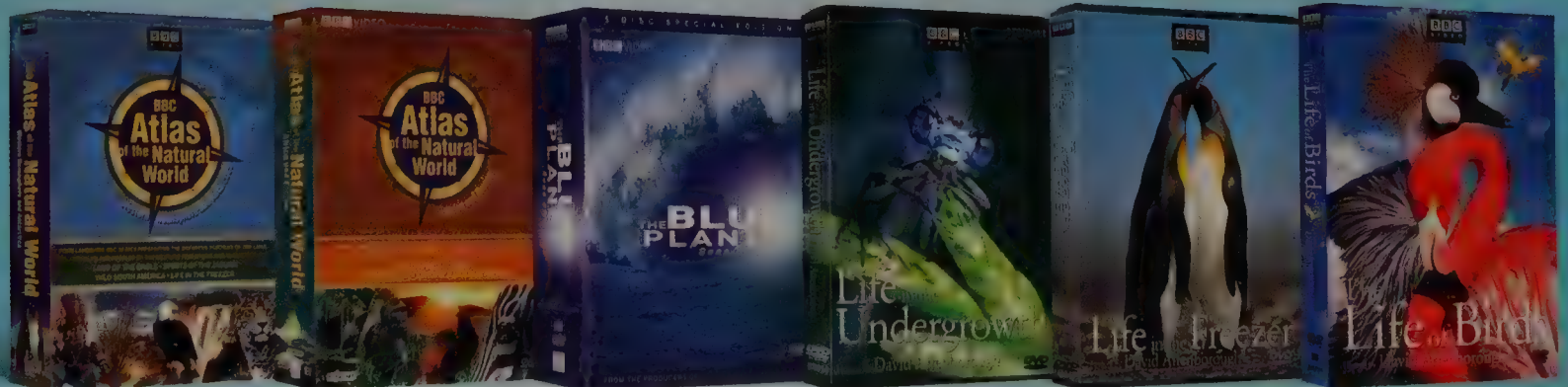
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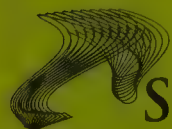
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SARAH GREY THOMASON



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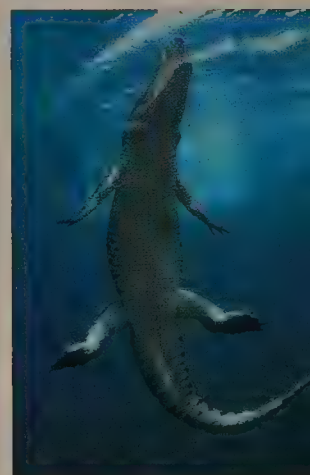
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THE NATURAL MOMENT

Lynx Jinx

Photograph by Michael Quinton

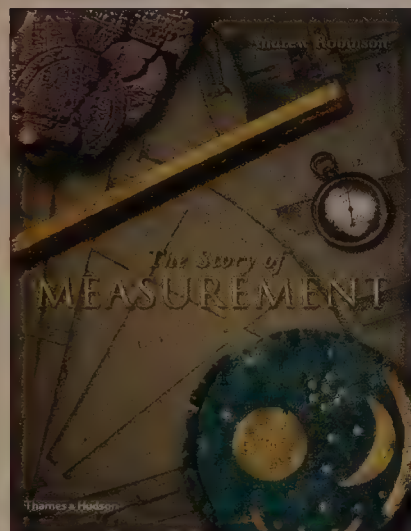




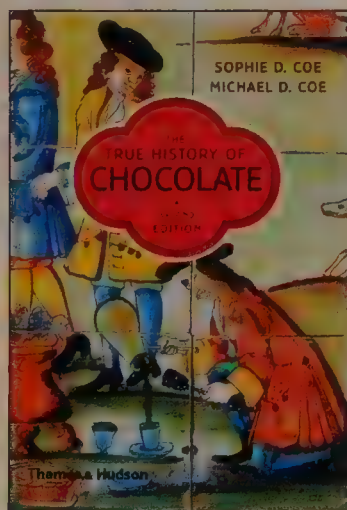
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THE NATURAL MOMENT

◀ See preceding two pages

Caught in the clutches of a cat? You're not alone. In more than 38 million U.S. households, 90 million domesticated cats have owners wrapped around their little pinky claws and are lapping up household luxuries. But the six other feline species in North America—the bobcat (or bay lynx), the Canadian lynx, the jaguar, the jaguarundi, the ocelot, and the puma—must prey in ever more precarious and taxing settings. In fact, of the thirty-six wild cat species in the world, more than two-thirds are either endangered or at risk.

Bobcats, like the one pictured here near the Snake River in southeastern Idaho, are currently classified as being at risk, but that's been up for debate. Six months ago the United Nations considered removing the bobcat (*Lynx rufus*) from its protected list. Many U.S. officials favored such a change in order to ease the trade in bobcat skins. Over 50,000 skins are brought to the global market every year, making the bobcat the most traded cat species on the planet, with the U.S. as the leading exporter.

Are there really that many bobcats to spare? The pointy-eared creatures range widely, from Ontario to California to Florida. Yet the last bobcat

census was conducted more than a quarter century ago, so only rough population estimates exist today. Apart from that, an *L. rufus* skin can be indistinguishable from some other, more vulnerable species, even after DNA testing. Therefore, out of extreme concern for the other cats, the U.N. voted to keep the strictures in place.

Photographer Michael Quinton certainly wasn't out for a pelt when he spotted this bobcat several winters ago in Market Lake Wildlife Management Area. About twice the size of a domestic cat, it was stalking a fat muskrat. The solitary hunting creatures usually prefer dusk and dawn, but in tough seasons, when rabbits and rodents (even deer) are scarce, longer hours prevail.

"The muskrat had a moment of bravery when it lunged at the bobcat," recalls Quinton, "but it was quickly killed." The cat then proceeded to toss the carcass repeatedly and roll around on it. Finally, after eating about half of its catch, the bobcat ran off with the remains. Having no guarantee of its next meal, the cat likely cached the leftovers under the snow—in its own version of domesticity, refrigeration.

—Erin Espelie



Michael Quinton

After living on the edge of Yellowstone National Park for years, Quinton left in favor of a "real wilderness": a home near Wrangell-Saint Elias National Park in Alaska. There Quinton set up a base for his video and photography production. See www.michaelquintonphotography.com for more of his work.



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Raja Ampat, Papua, Indonesia
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WORD EXCHANGE

Hail from the Chief

In case you missed Peter Brown's kind introduction last month, I have now succeeded him as Editor-in-Chief. As it happens, one of the first initiatives I've taken is to use the term "Editor in Chief" without hyphenation, to better conform with our preferred reference dictionaries. Other than that, don't expect wrenching surprises; I wouldn't be approaching my thirtieth year on the staff of *Natural History* if I were not pleased with what we do.

In my view the magazine's hallmark remains the publication of accessible articles by actively engaged scientists describing their primary research. An example is linguist Sarah Grey Thomason's report, in this issue, on the few remaining fluent speakers of Salish-Pend d'Oreille, a Native American language of the Pacific Northwest, and on the threatened extinction of between 60 and 90 percent of the languages spoken around the globe today. Still, we happily make room for those whose stock-in-trade is writing: that enables us to bring you Michael C. Blumenthal's engaging account of his experience in South Africa as a volunteer caring for orphaned baboons. And of course we are proud of our stable of columnists (regrettably, however, Neil deGrasse Tyson's loyal fans will have to make do with fewer "Universe" columns each year, because his other commitments have forced him to cut back).

We will be tweaking a few ingrained practices. For one, you will now find the feature authors' biographical notes at the ends of their articles, instead of on a separate contributors' page. And I'll be keeping any future editorial notes short, to allow more room for your letters.

Vittorio Maestro

Stand Up Straight

Ian Tattersall gives a fine summary of bipedalism in early hominids

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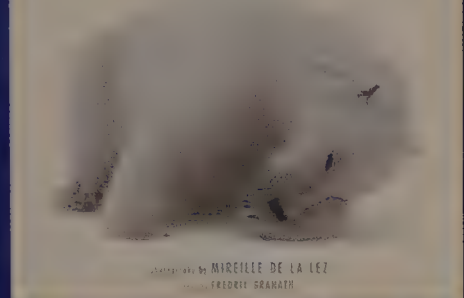
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Outward Bound

By Robert Anderson

In 1958 the prolific science fact and fiction writer Isaac Asimov published "Our Lonely Planet," an article in which he reasoned that given the tremendous distances—four light-years even to the nearest star after the Sun, Proxima Centauri—interstellar space travel would take too long to be practical. But with more than 200 planets now discovered in orbits around nearby stars, it's nice to imagine that we could someday get to one that looks hospitable. On the Internet, Google Earth's new Sky feature makes such flights of fancy a snap. Please visit the magazine online (www.naturalhistorymag.com), where I review Web sites devoted to virtual space travel.

ROBERT ANDERSON is a freelance science writer who lives in Los Angeles.

WORD EXCHANGE

Continued from page 6

["Lucy Goes Walkabout," 10/07] so I was surprised to see that Viktor Deak's cover illustration shows Lucy's close relative in a semi-erect, bent-knee stance. I had the good fortune to examine Lucy when she was in Donald C. Johanson's lab in Cleveland, and I can assure you that the anatomy of the lower back, hips, feet, and knee and ankle joints all provide clear evidence that those early hominids stood just as erect as we do.

C. Loring Brace

University of Michigan
Ann Arbor, Michigan

VIKTOR DEAK REPLIES: The *Australopithecus garhi* in the illustration (which is part of a larger mural on display at the Houston Museum of Natural Science) is shown in a slightly crouched stance, shielding her child. My intent was to catch her at the moment of pulling away from a possible predator (in this case, the viewer)—a gesture that neither human nor ape would do with locked knees. After years of studying Lucy's bones with Gary Sawyer and Ian Tattersall, I have noted their striking similarity to modern human bones, but one can't ignore the fact there are also a lot of differences. Lucy's bell-shaped, robust upper body and small gluteus maximus (well-suited to climbing) probably gave her a slightly different posture from ours.

Lucy Goes Walkabout, but Arizona State University does not. ASU is in Tempe and the University of Arizona is in Tucson.

Paul Aizley

Las Vegas, Nevada

THE EDITORS REPLY: Indeed! We mistakenly stated that the Institute of Human Origins at Arizona State University, where Donald C. Johanson works, is in Tucson. As several of our readers pointed out, ASU is in Tempe. Thanks for keeping us on our toes.

No Translation Necessary

I read Neil deGrasse Tyson's discussion of the space race ["Fellow Traveler," 10/07] with great interest since I worked with the von Braun group on the creation of Jupiter-C, the rocket that launched *Explorer 1*. What Mr. Tyson didn't mention was that Wernher von Braun's German ties gave him inside knowledge of Russia's activities, so he knew about the *Sputnik* program before the rest of America. In fact, we built Jupiter-C six months before *Sputnik 1* was launched and put it in a warehouse! When the Secretary of Defense got around to asking von Braun to put up a satellite, it took only two months to launch *Explorer 1*. The joke going around at the time was: "Do you know how *Explorer 1* was able to speak to *Sputnik*? They both spoke German!"

A.P. Warren, Retired NASA Engineer
Gallion, Alabama

Translation Necessary

Robert Anderson's mention of *Sputnik 1*'s "evocative sounds" ["Beep Beep," 10/07] reminded me of that October morning in 1957 when I hastened from class to my dorm room to switch on my old Hallicrafters S-40B. Fortunately I had the presence of mind to switch on the beat frequency oscillator (BFO), which converted *Sputnik*'s hisses into a few fading beeps. Ham radio operators working with Morse code used the BFO to convert continuous wave (CW) signals into audible beeps. A number of my memory cells have faded into retirement, but I remember thinking that the weak CW signal emitted by *Sputnik* could easily have been overshadowed by the signal emanating from WWV, the national standards station broadcasting from Ft. Collins, Colorado. I suspect that many who reported hearing *Sputnik*'s beeps may have been using smaller, less sensitive shortwave radios lacking BFO capability and mis-

Continued on page 63

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Crested auklets court during mating season.

Eau de Bird

Crested auklets are little flirts. Not only do both sexes of that northern seabird sport showy crest feathers and bright orange bills, the better to woo each other; they also produce a distinctive citrus scent, fragrant even to people. The source of the aroma had been unknown, but now Hector D. Douglas III of the University of Alaska Fairbanks has discovered it: specialized feathers and tissue between the birds' shoulders.

According to Julie C. Hagelin of Swarthmore College in Pennsylvania, the odor may serve as a kind of perfume, an olfactory ornament that attracts mates. She points out that the citrusy odor is emitted only during the breeding season, attracts both sexes when daubed on stuffed models, and is the focus of a "ruff-sniff" behavior in which birds dip their bills under the nape feathers of prospective

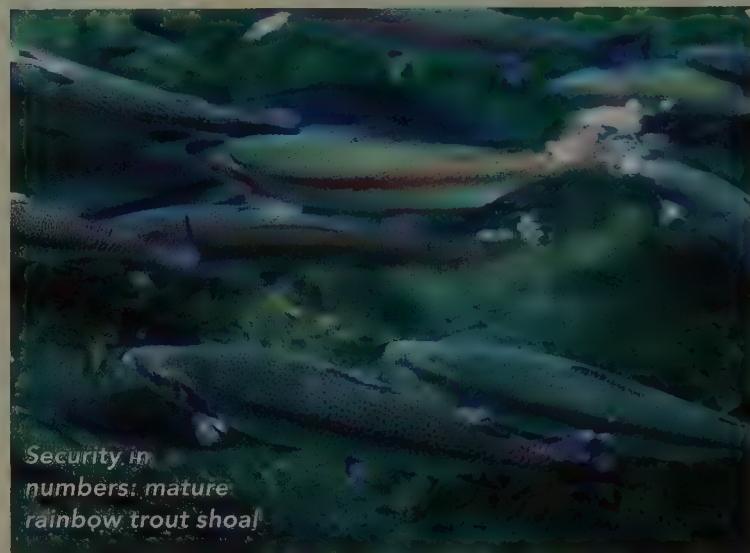
mates and social rivals. (Avian biologists, Hagelin notes, are just beginning to recognize that some birds communicate with odor, as other vertebrates have long been known to do.)

Douglas goes a step further. He discovered that the scent's constituent chemicals deter mosquitoes and ticks, which plague the birds. He's watched auklets rub their bills, heads, necks, and breasts—hard-to-preen body parts—against the nape feathers of their mates, who stand with necks outstretched in offering. Partners usually reciprocate several times in an act of mutual anointing. Insect repellent, Douglas thinks, could make a valuable engagement gift: a strong scent might advertise one's fitness as well as the ability to chemically protect one's mate and chicks. (*Naturwissenschaften, Journal of Ornithology*) —Stéphan Reeb

A Flake of Foresight

Fish often find strength in numbers: groups, called shoals, can spot predators quickly, confuse their assailants, and reduce an individual's chances of becoming lunch. Yet fish don't always have an eye for such togetherness—particularly when their eyes are afflicted by parasites.

Larvae of the eye fluke *Diplostomum spathaceum* infect a fish's lenses, causing a cataract to form that impairs vision. In laboratory experiments, Otto Seppälä and two colleagues from the University of Jyväskylä in Finland observed that parasitized juvenile rainbow trout formed smaller, sparser shoals than trout that were parasite-free. The effect was particularly pronounced when Seppälä and colleagues sent an object flying overhead in imitation of a predatory bird. The semi-blind



Security in numbers: mature rainbow trout shoal

fish seemed to have trouble finding their buddies just when they needed protection most.

Seppälä suggests that the reduced penchant for shoaling makes the young trout more vulnerable to attack by birds of prey. But what's bad for the fish is good for the fluke. Like other trematodes, *D. spathaceum* has a complex life cycle; it jumps from snail to fish to bird. By impairing the vision of their fish hosts, eye flukes improve their odds of going airborne. (*Animal Behaviour*) —S.R.

Fitness for Grandmas

Menopause is puzzling from an evolutionary standpoint. Why should healthy women stop having children after age fifty when doing so curtails their reproductive success? Actually, it doesn't. A new study supports the hypothesis that menopause frees up older women to help care for their grandkids, whose improved survival overcomes the lost opportunity to have more children.

Daryl P. Shanley of Newcastle University in England and three colleagues analyzed

an unusually complete trove of demographic data collected in two Gambian villages between 1950 and 1975. Modern medical care only became available to the villagers in 1975, and life was pretty basic before that, so Shanley says the data offer a unique glimpse into relatively natural human fertility patterns.

His analysis revealed that infant mortality during the first two years of life declined by half when a maternal grandmother was present. Predictably, moms helped even more,

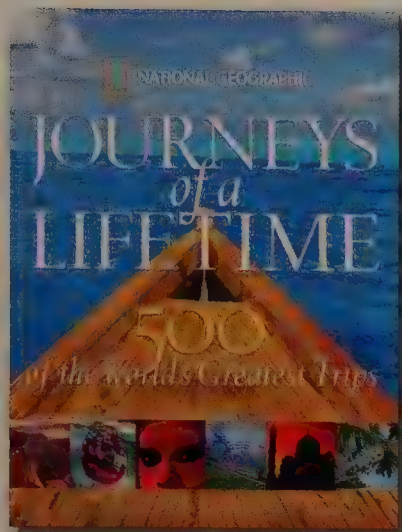
But infant survival was not influenced at all by fathers, siblings, grandfathers, or, notably, paternal grandmothers (it makes sense for grandmothers to devote more time to their daughters' babies than to their sons', since paternity is uncertain).

Through mathematical modelling, Shanley calculated that grandmotherly care would be cut by more than two-thirds if menopause occurred at age sixty-five instead of fifty. Delayed menopause would reduce the fitness of the grandkids—and the grandmas. (*Proceedings of the Royal Society B*) —S.R.



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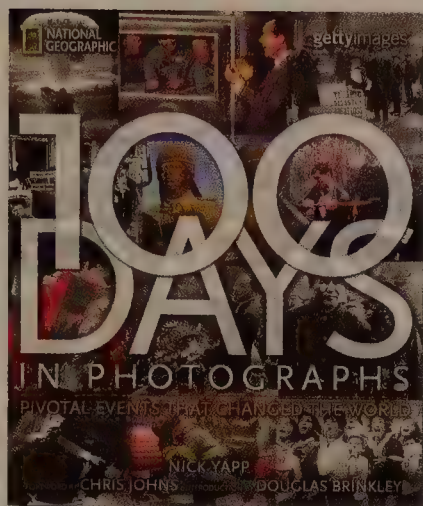
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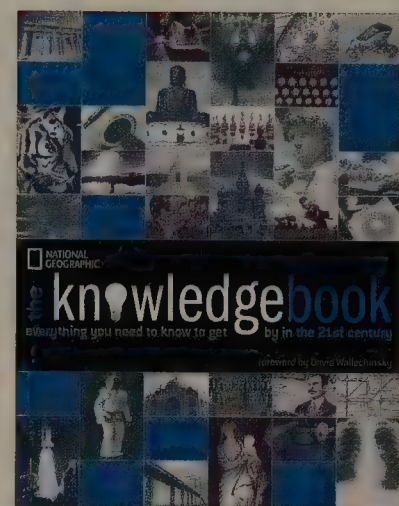
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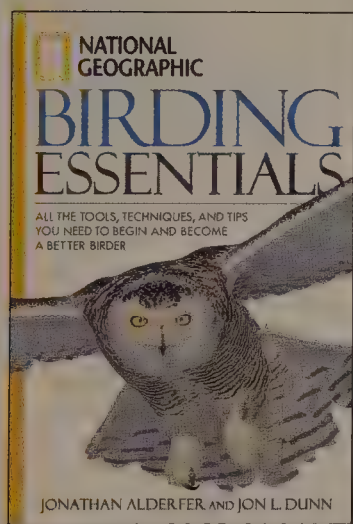
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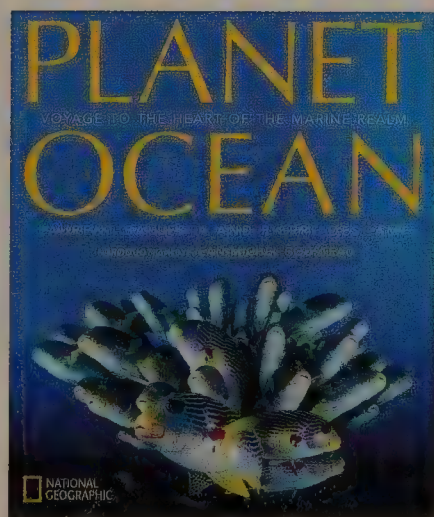
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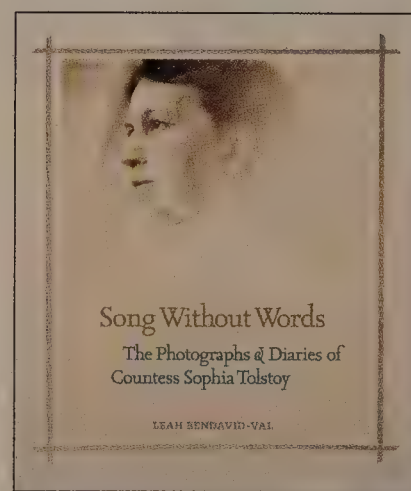
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Saltie swims in its element

The Croc Came Back

Saltwater crocodiles aren't known for their sentimentality, but they are prone to bouts of homesickness, according to a new study. Conducted with the help of the late Steve R. Irwin—the "crocodile hunter"—the study shows that displaced "salties" will travel as far as 250 miles to return to their home estuaries.

Craig E. Franklin of the University of Queensland and several colleagues, including Irwin, captured three large male crocodiles on the Cape York Peninsula in Australia's northeast tropics—no mean feat considering the beasts weigh more than 500 pounds apiece. After securing satellite transponders to the crocodiles' backs, the team helicoptered them thirty-five, sixty, or ninety miles away from their capture sites.

After lingering in their new environs for as long as three months, the crocodiles made a beeline along the coast for their old haunts. The endurance champ—a fifteen-footer who'd been airlifted across the peninsula—swam 250 miles clear around the coast. He covered as many as nineteen miles in a single day, belying the notion that crocodiles are burst swimmers and cannot exert themselves for extended periods.

The study also shows that salties are gifted navigators; Franklin speculates that they, like their closest relatives, birds, use clues from the sun and Earth's magnetic field, as well as their senses of sight and smell, to find their way. (PLOS ONE) —Brendan Borrell

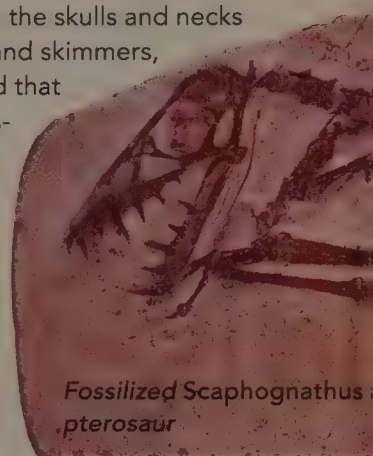
Did Skimming Fit the Bill?

Today, only three bird species have the chops to skim for their supper. Black, African, and Indian skimmers fly low, pushing their lower beaks through the water, then snap their jaws shut when they hit a fish. Anatomical similarities between skimmers and pterosaurs—ancient flying reptiles that included pterodactyls—have led some paleontologists to suggest that pterosaurs also ploughed the water's surface. But Stuart Humphries, now at the University of Sheffield in England, begs to differ.

With three colleagues, Humphries made casts of the lower beaks of skimmers and pterosaurs, pulled the casts through water, and measured the drag force water exerted on the beaks. The team calculated that overcoming drag consumes a fifth of the energy that modern skimmers devote to flying—a substantial handicap that probably explains why skimming is so rare. As for the pterosaurs, Humphries measured

such great drag on their beaks—as much as 68 percent of what their total energy expenditure would have been, he calculated—that flying while skimming would have been impossible for all but the smallest species. The team also compared the skulls and necks of pterosaurs and skimmers, and discovered that pterosaurs possessed few of the thirty adaptations that enable skimmers to do their thing.

It's more likely, says Humphries, that when the largest flying creatures of all time fished, they snatched their meals from the water in one targeted swoop. (PLOS Biology) —S.R.



Fossilized Scaphognathus pterosaur

On the Trail of a Snail

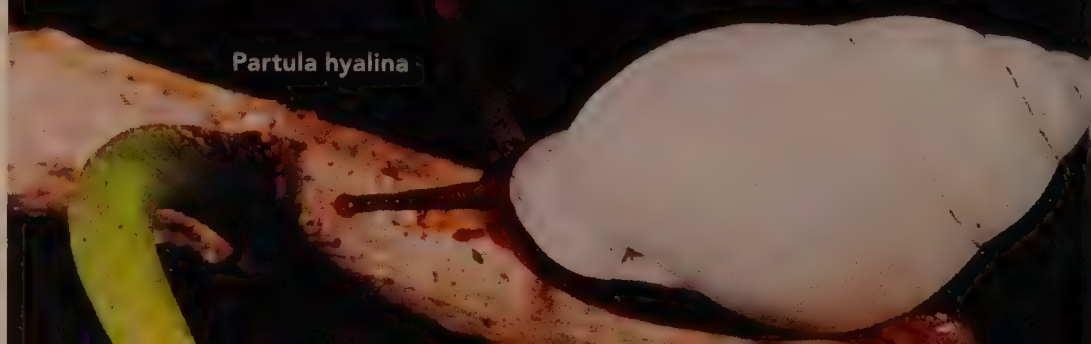
In 1970 John B. Burch, a malacologist visiting Tahiti, collected *Partula hyalina* snails bearing pretty white shells that islanders often fashioned into jewelry. Little did he know that the species, along with numerous others on South Pacific islands, would be devastated by a carnivorous snail introduced a few years later to control agricultural pests. Now that the damage to the native fauna has been done, however, Burch's snails have helped solve a longstanding malacological mystery: how did *P. hyalina* come to live only on Tahiti, on two of the Cook Islands (600 miles to the southwest), and on four of the Austral Islands (500 miles to the south)—but on none of the region's myriad other islands?

Enter Taehwan Lee of the University of Michigan and several colleagues. They recently compared portions of

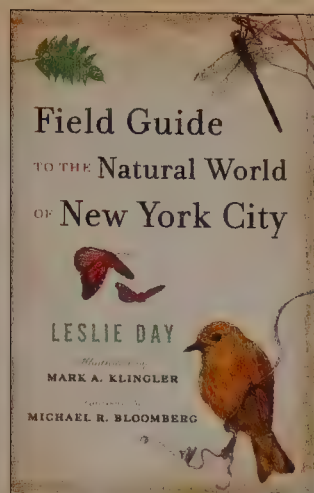
DNA from Tahitian *P. hyalina* snails, collected by Burch and others, with those of individuals from the Cook and Austral islands. The comparison showed that the species originated on Tahiti, and was introduced to the outlying islands within the past 30,000 years.

But how did it get there? *P. hyalina* belongs to a lineage that comes in two color morphs: the white one and a darker one that lives only on Tahiti. Ancient Polynesians, the team thinks, selected the white-shelled morph to establish colonies of Tahitian snails on the outer islands as a source of shells for jewelry. If that's the case, they did *P. hyalina* a big favor: it is all but extinct on Tahiti and now thrives only on its new, far-flung island homes. (Proceedings of the Royal Society B)

—Rebecca Kessler



Partula hyalina



Field Guide to the Natural World of New York City

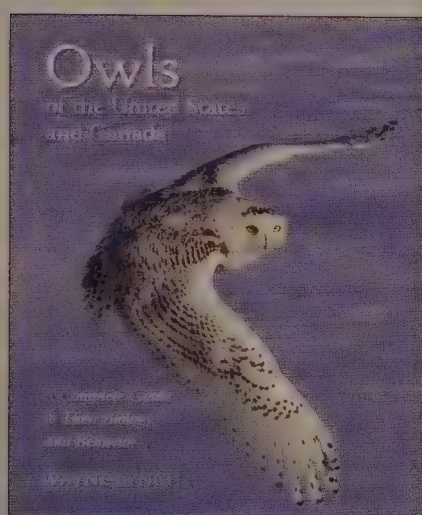
Leslie Day

illustrated by Mark A. Klingler • foreword by Michael R. Bloomberg

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—Richard Ellis, author, artist, and research associate at the American Museum of Natural History

THE PURSUIT OF KNOWLEDGE

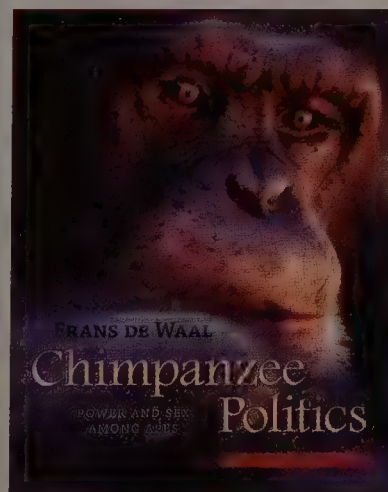


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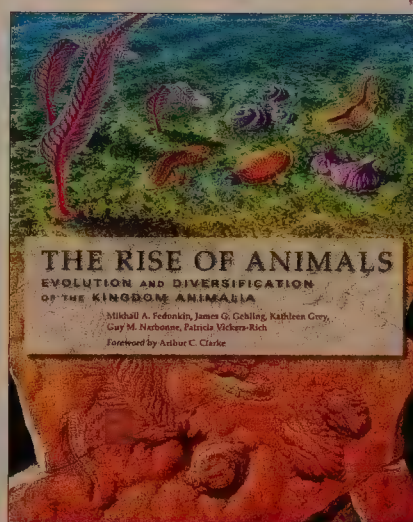


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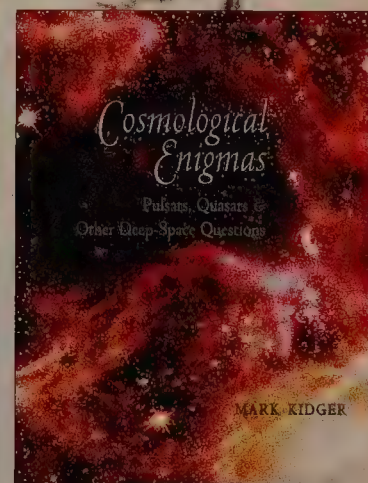
The Rise of Animals

Evolution and Diversification of the Kingdom Animalia

Mikhail A. Fedonkin, James G. Gehling, Kathleen Grey, Guy M. Narbonne, and Patricia Vickers-Rich

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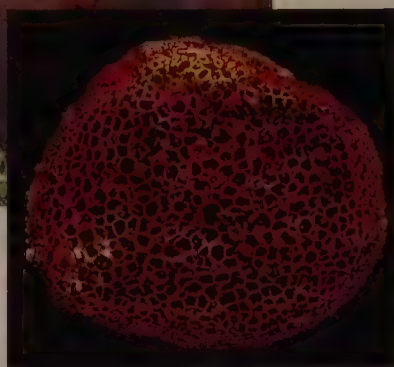


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Black layer found in Arizona, above, and elsewhere containing carbon spheres like the one at right, magnified 130x and colorized, suggests an extraterrestrial cause for a mass extinction.



It's Not Just the Heat

It's the humidity, or so the satellites say. They've been measuring a steady rise in atmospheric moisture over the oceans since 1988, when they first started gathering such data. The mugginess seemed a likely hallmark of global warming, and a new study now shows that human activity is definitely the cause.

The satellite data indicate that the column of atmosphere above every square yard of ocean now holds nearly three more cups of water than it did two decades ago, according to a team led by Benjamin D. Santer of the Lawrence Livermore National Laboratory in California. Combining results from all

twenty-two of the world's major climate models, Santer and his team discovered that the increase came not from solar radiation, volcanoes, or El Niño—factors that climatologists had considered—but from the greenhouse gases people have been pumping into the air.

Greenhouse gases warm the atmosphere and thereby increase its moisture-holding capacity. But water vapor is itself a greenhouse gas—a wicked feedback loop, if ever there was one. Of course, a fraction of the extra vapor condenses and forms clouds, which could offset some of the warming.

Beware though: high humidity can trigger intense hurricanes, the kind of cloudy weather we can definitely do without.

(PNAS)

—S.R.

Camels 0, Comet 1

Thirteen thousand years ago camels, giant ground sloths, and mammoths roamed a lush North American landscape, along with the continent's earliest human inhabitants, the Clovis people. A mere hundred years later, however, the megafauna and the people had vanished forever, and an ice age that would last a millennium had begun. What happened? New research points to a seemingly "far out" cause: an enormous comet that exploded over present-day Canada.

More than two-dozen scientists, led by Richard B. Firestone of the Lawrence Berkeley National Laboratory in California, studied a distinct, inch-thick layer of black sediment deposited 12,900 years ago at sites across North America. Fossils of the extinct megafauna and Clovis artifacts have never been found within or above the layer. At the

layer's base, the team discovered minerals and particles that are typical of extraterrestrial objects, as well as soot and charcoal suggesting massive fires.

Firestone and his team think the layer formed immediately after one or more extraterrestrial objects—possibly fragments of a comet—hit an icy region of northern Canada. The explosive impact sent a devastating shock wave and thermal pulse across the continent, incinerating animals and landscapes. It would also have destabilized the ice sheet, upsetting ocean circulation and triggering the ice age. Lingering environmental effects of the impact—particularly a lack of food—contributed to the mass extinction, which included the loss of thirty-five mammal genera, the team concludes.

(PNAS)

—Harvey Leifert

Earlier Birds

Birds returning from a winter's retreat are showing up in England earlier and earlier each spring as a result of global warming, a new study confirms. Unexpectedly, populations in decline show a less pronounced shift than thriving ones do, sparking fears that ecologists have underestimated the effect of rising temperatures on migratory birds.

Led by Tim H. Sparks, an ecologist at the Natural Environment Research Council in Monks Wood, England, a

team of investigators studied up to fifty-six years' worth of data, gathered at six English locales, on the arrival and departure dates of thirty-three migrant bird species. On average, they discovered, the birds are arriving in the spring twelve days earlier than they did fifty years ago. That's a big change, and it mirrors advances already noted for migratory birds throughout Europe and in the United States. But the change was even bigger among species, such as the blackcap, whose numbers are on the rise in England: they

now arrive as many as twenty days ahead of schedule. By contrast, species with declining populations have been flying in just five days early.

Why the difference between thriving and declining species? Sparks thinks observers may spot the earliest birds more readily when a species is abundant. If so, the true average advance in European and American arrival times may be even greater than actually measured because, sadly, many migrant bird species are on the wane. (*Journal of Ornithology*)

—S.R.



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Hiber Nation

Understanding how creatures put their lives on hold could yield therapies for a variety of human ills.

By Olivia Judson

As the nights close in and winter takes hold, I get a hankering to burrow into my duvet, curl up, and hibernate until spring. But alas, humans are not among the large and diverse group of animals that can put themselves on hold for a few months. At least, not yet.

Human hibernation is a hot topic, as I discovered one afternoon when I happened across the *Journal of British Interplanetary Science*. Space agencies are interested because the ability to hibernate on demand would come in handy on long-haul space flights. The immortality crowd is interested too: if you've got an incurable disease or simply won't settle for an 80-year-life span, wouldn't it be great if you could put your head down, catch forty million winks, and wake up when medical science catches up? But the applications aren't all so futuristic; some are much closer to home. For instance, Matthew T. Andrews, a biologist at the University of Minnesota in Duluth, foresees that discoveries from hibernation biology will be useful in treating everything from heart conditions and hypothermia to obesity. Indeed, writing earlier this year in the journal *BioEssays*, he argued that "there is tremendous potential for applying hibernation strategies to improve the human condition." Gosh. I threw off my duvet and went to investigate further.

First off, I discovered that hibernation takes different forms in

different animals. A black bear, for example, drops its body temperature by only a few degrees, and spends the winter in a kind of deep and continuous sleep. During that time, it neither urinates nor defecates. For small mammals such as bats and ground squirrels, in contrast, hibernation typically features profound drops in body temperature, during which the animal is inactive, punctuated by regular bouts of warming up to normal and rousing into activity for some hours. The Arctic ground squirrel in particular may be the most extreme case. During regular life, its core body temperature, like ours, hovers around 98.6 degrees Fahrenheit. But during hibernation, its core body temperature can actually fall below freezing, to as little as 26.8 degrees, for days at a time. How do Arctic ground squirrels manage that? They supercool.

Supercooling is what happens when the temperature of a liquid falls below its freezing point yet doesn't freeze. That can happen if a liquid has no nucleating agents—no particles around which crystals can form. But add a particle—a piece of ice, say—to a cup of supercooled water, and *pow!* The entire cup of water will freeze instantly. Being able to supercool is rare among mammals—but popular among insects. In Alaska, yellowjacket queens of the species *Vespula vulgaris* survive the cold, hanging by their mandibles for nine months in a dry, snow-free cavity,

by allowing the fluids in their bodies to supercool. A supercooled yellowjacket can drop her temperature to as low as 3 degrees, but rather miraculously avoids turning into a waspsicle. Bring her into contact with snow, however, and again, *pow!* She freezes solid—which kills her. Other insects can get even cooler: the beetle *Rhagium inquisitor*, otherwise known as the ribbed pine borer, can supercool to -24 degrees. Is a supercooled Arctic ground squirrel at risk of freezing solid? It's possible, but unlikely. Its skin would have to be pierced by an icicle or something like that.

HIBERNATION, ON MANY LEVELS, looks passive, almost like a temporary death. In a small mammal, the body is cold, the heart rarely beats, the animal scarcely breathes. A hibernating little brown bat, for example, may take a breath less often than once an hour. The cellular machinery shuts down, too: little DNA is copied, few proteins are made. But hibernation is far from being a full suspended animation. For one thing, many hibernating animals remain alert to unusual

noises or disturbances. Cough loudly in a cave full of hibernating bats, and they will start to rouse. Stride into a bear's den, and the bear will wake up—and it probably won't be pleased to see you. Moreover, hibernation is tightly regulated. Ground squirrels move in and out of hibernation with clockwork precision—somehow, they measure time—and their body temperatures are always kept a bit higher than the temperature of their dens.

Hibernation seems to have evolved as a way to save energy when food is scarce, rather than a way to bypass winter months. That is why it isn't found only in cold climates. For instance, the fat-tailed dwarf lemur—a small primate that lives in Madagascar—hibernates to escape not cold, but drought. The animal beds down in a treehole, often snuggled with its mate and

perhaps a couple of their offspring, for as long as seven months, even though the outside air can reach a balmy 85 degrees.

But cold climates do encourage energy-saving methods. Mammals maintain their high body temperatures by burning fuel, and it costs more to stay warm when the difference between the usual body temperature and the outside air is large. It costs more for a small mammal to adjust to dropping temperatures than for a big one (smaller animals lose heat faster). In short, it is hard for an animal the size of a mouse to stay warm when the weather is be-

low freezing for weeks on end; thus, lowering the body's thermostat saves on heating bills. So it's all the more mysterious that ground squirrels bother to warm up every ten days or so. Warming up is expensive. In-



deed, that's the main energetic drain of hibernating.

Perhaps it's necessary to have a brief systems check every so often, depending on housing conditions. For instance, a fat-tailed dwarf lemur doesn't bother to rouse if it's hibernating in a poorly insulated tree-hole, one that lets air temperature exceed 85 degrees. Instead the lemur abandons control of its body temperature altogether, letting it (and presumably also its metabolism) fluctuate with the temperature of the air. But a lemur that's settled into a tree trunk that has thick walls and a cool interior—a castle among tree trunks—keeps its body temperature steady at 77 degrees, and rouses for a few hours about once a week. (Maybe the reason bears don't do such systems checks is that they never let their bodies get much colder than about 90 degrees.)

How does an animal begin to hibernate? It goes to sleep. Indeed, one of the first things that happens in slow-wave sleep (as opposed to rapid-eye-movement sleep) is that body temperature drops a little. But whereas your body temperature won't drop more than a degree or so, the body temperature of a hibernating animal keeps going down as its metabolic processes slow down. Some animals let their temperatures drop low on a daily basis, essentially hibernating for a few hours in the night (or day)—a condition known as torpor. But, interestingly, many animals, such as hummingbirds, that become torpid do not hibernate for longer periods.

And if an animal begins to hibernate by going to sleep, what does it do upon rousing from hibernation? Oddly, the first thing a ground squirrel does is . . . take a nap. Why? No one knows.

BUT WHAT DOES ANY of this have to do with the human condition? It turns out that when they hibernate, animals overcome what currently look to us like intractable medical problems. For instance, cold-temperature hibernators, such as bats and ground squirrels, put themselves through rigors that would kill us. Most mammals that don't hibernate—such as mice, rats, and humans—die of heart failure if you cool the heart below about 70

What does an animal do upon rousing from hibernation? Oddly, the first thing a ground squirrel does is . . . take a nap.

degrees. Similarly, the hibernating brain gets almost no oxygen, yet the animal doesn't suffer brain damage. Understanding how that works could lead to better treatments for stroke and head trauma.

Indeed, ground squirrels have much to teach about brain regeneration. Studies of the golden-mantled ground squirrel show that during hibernation they retract many of their dendrites—the tendril-like nerve-cell endings that receive information from other neurons. Such a disappearance of dendrites is usually associated with senility. Yet each time the animal rouses, though it's only for a few hours, it regrows its dendrites. What's more, the dendrites grow faster when the animal emerges from hibernation than they do during embryonic development—a period usually thought to be the pinnacle of speedy neural growth. In the brain of an embryonic rhesus monkey, for example, den-

drites can grow 114 microns per day (about the thickness of a human hair). The freshly roused adult ground squirrel can accomplish the same growth in just two hours. Strange.

Why would an animal repeatedly dismantle and then rebuild the connections in its brain? Again, the answer isn't clear. One possibility, favored by the hibernation expert H. Craig Heller, a professor of biological sciences at Stanford University, is that during hibernation, it is too difficult to properly maintain the dendrites, so it's better to get rid of them and start over than to have to repair them. In support of that idea, he and his colleagues have shown that retraction is more extensive in animals that get colder. That makes sense: the lower the body temperature, the more complete the general shutdown, and the harder it would be to keep the dendrites in good order. Irrespective of why it happens, though, understanding how ground squirrels regenerate their brains might help develop therapies for the regeneration of damaged human ones.

SEVERAL OTHER ASPECTS OF hibernation turn out to be of potential medical interest. Take black bears. They don't move for months—they often start hibernating in October and don't emerge until April—yet their muscles don't waste away. A man confined to bed for six months would not be so lucky: his muscles would atrophy to about 20 percent of their prior strength, and on getting up, he'd find it difficult to walk. It isn't clear how the bears manage to keep their muscle tone, though preliminary studies suggest that hibernating bears engage in regular episodes (that is, three or four times a day) of vigorous muscle contractions, a k a shivering.

At the same time, bears and other hibernators lose weight—Bears and their kind, because they keep their body temperatures relatively high; the deep hibernators, because of the repeated bouts of warming. More-

over, hibernation burns up fat fast. For those with six months to spare, I foresee the hibernation diet, with the slogan: "Lose weight by doing nothing!" More seriously, hibernation could shed light on obesity and how to treat it. An animal preparing for hibernation suddenly starts gaining weight. The fat-tailed dwarf lemur doubles its mass in a few weeks, storing most of the fat in (you guessed it) the tail. Thus, understanding the underlying mechanisms of weight gain coupled with the subsequent weight loss could eventually lead to new anti-obesity drugs.

BUT HERE'S THE MOST radical research. Instead of trying to mimic natural hibernation, cell biologist Mark Roth and his colleagues at the Fred Hutchinson Cancer Research Center in Seattle have taken a different approach to suspended

animation. By exposing mice to tiny quantities of hydrogen sulfide gas—which in large amounts is poisonous—they seem to be able to switch off the body's ability to keep up its normal temperature. Sensors record a precipitous drop in metabolism along with temperature. In this fashion, the biologists can cause the mice to appear dead—but when the gas is removed from the air six hours later, the mice perk up, apparently unharmed.

Roth hopes his research will lead to new ways to approach surgery and the treatment of strokes; others have wilder ideas. One aspiring Methuselah, Florian Müller, argues that reducing body temperature by just a few degrees would reduce metabolism and thus increase life span. Writing in the journal *Rejuvenation Research*, Müller, now a post-doctoral fellow in aging studies (and not

yet thirty), proposes living in a temperature-controlled box and breathing air mixed with minute quantities of hydrogen sulfide (to bring his temperature down just a smidgen) until medicine has progressed to the point where aging is abolished altogether. Of course, he writes, "one would have to be willing to tolerate . . . the slowing of other biological functions (e.g., probably reasoning, movement)." Is it worth it? Müller thinks "probably yes."

Me, I think I'll take a different approach: follow the swallows and the swifts, and go south for the rest of the winter.

OLIVIA JUDSON, a research fellow in the Division of Biology at Imperial College London, is the author of Dr. Tatiana's Sex Advice to All Creation: The Definitive Guide to the Evolutionary Biology of Sex (Owl Books, 2003).



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Skating through the Ages

Skaters have been speeding up over the centuries, thanks to better footwear that allows longer strides for maximum efficiency.

By Adam Summers ~ Illustrations by Tom Moore

My little brother and I grew up on Rollerblades, the terrestrial version of ice skates. We raced on the rumpled streets of New York City, from Greenwich Village north to Central Park, ecstatic not to be circling a small oval of ice. In those days I held two major misconceptions about skating: I imagined that we were pioneering a new form of long-distance transport, and I thought skating was easier than running because of its gliding phase. In neither case was I close to the truth.

As far back as the Bronze Age, 3,000 years ago, skates helped people travel more widely. And it turns out that skating is extremely efficient, taking advantage of biomechanical properties of the muscles throughout the movement cycle—not only during the glide.

To an unmechanized Europe and Russia, ice skates were one of the first useful tools for making winter



trips between towns.

And since the joys of skating are best appreciated on long stretches of smooth black ice, it comes as little surprise that ice skates made their first appearance on relatively flat, snowless waterways.

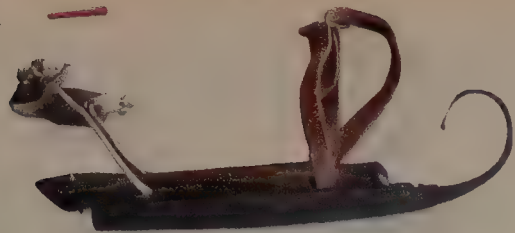
Early skates were constructed of trimmed horse or cow bones, pierced at one end and strapped to the foot with leather thongs. Rather than being powered by the classic skating motion, those beauties were used in tandem with a long stick; skaters straddled the stick and poled themselves along. Bone blades gave way to iron ones and then to steel. By the 1800s the idea of a steel blade grafted to a fitted leather boot had firmly taken hold. (Although

most skaters still use that design today, the ultimate innovation in the skating world was the “klap” skate; it has a hinge that allows the skater to extend the ankle while pushing, which boosts speeds by 5 percent.)

The advent of thinner blades and a firm attachment to the foot signaled a transition to the longer strides of a modern skater. Those extended strides give skating its advantage over unassisted modes of transport (such as running) because, as it happens, the slower a muscle contracts, the greater the force it develops. To understand how that force difference works on the molecular level, imagine the muscle fiber as a “rope”: slow contractions pull the rope hand-over-hand, as if hauling a bucket from a well; rapid contractions grab and quickly release the rope—delivering a smaller relative force. Since skaters’ leg muscles can contract quite slowly, even at very high speeds, they gener-

Runner at the same given speed as a skater might take six steps for every skating “step”—generating less force per leg-muscle contraction. If both athletes exerted the same effort, with heart rates of 120 beats per minute, say, the skater would be almost four times faster.



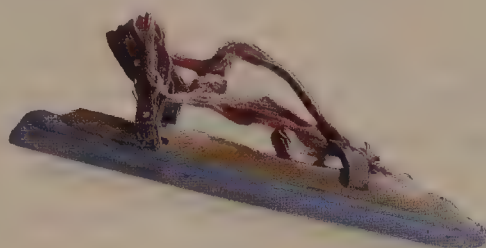


ate more force during each stride cycle. And that slow contraction can be maintained thanks to the fact that less lateral force—the outward push against the ice—is needed at higher speeds. Thus the strides get longer and the skate tracks become more parallel to the direction of travel [see the herringbone tracks that straighten and get farther apart as they pick up speed across the page].

HUMAN-LOCOMOTION biomechanists Federico Formenti of Oxford University and Alberto Minetti of the University of Milan collaborated to trace the efficiency of ice skates through history. Their aim was to measure the evident increase in efficiency from clunky animal-bone skates (1800 B.C.) to iron skates (A.D. 1200 and 1400) to steel skates (1700) to cutting-edge modern skates, also made with steel blades [the five skates used in the experiment are pictured here]. First the researchers fabricated authentic replicas of the ancient skates, adding only a somewhat safer binding to the oldest models. Then they found five retired professionals—short-track ice skaters—with a sense of adventure. After the skaters had familiarized themselves with the historic skates, they were equipped with a small

strap-on apparatus that measured their oxygen intake, heart rate, and (for three of the skates) leg movements. Each skater was then asked to skate both at a slow, comfortable pace and at a faster, more demanding pace with each type of skate. From those data, the researchers derived the energetic demand relative to speed of ice-skating on different kinds of skates.

The oldest bone skates used with the push pole simply would not go very fast; the pros only managed



a single speed of about 2.5 miles per hour (mph). Of course, even to achieve a steady, safe walking pace such as that would have been a big advantage to someone on a flat, icy river. The earliest metal-bladed skates that were tested allowed a near doubling of the slow, steady speed, but also permitted a fast gait of about 9 mph. Better bindings and thinner blades further enhanced speeds, culminating in a fast gait of about 15 mph with the modern non-klap skates that were tested.

Not surprisingly, the more modern skates delivered not only on speed but also on distance covered. By far the most impressive increases, though,

have to do with efficiency relative to speed. Consider a skater working herself to a point of exhaustion in ten minutes; on the oldest skates or the newest ones, she is putting in the same amount of energy. Yet on the newest blades she could travel considerably farther. Her stride frequency stays the same and her leg muscles continue to operate at high power, independent of forward speed (unlike a runner that squeezes out less force the faster the leg muscles move.)

Formenti and Minetti have gone on to test the bone skates in different locations, and have found that their benefits must have varied with the topography, particularly the number and length of lakes; Finland, with more than 60,000 lakes, seems the ideal locale and the likely place of origin for them. Considering my poor ankles, I might opt for the skates of yore on my next visit to the rink and punt around on horse metacarpals, big stick in hand to fend off any whizzing, would-be Bobby Orrs.



ADAM SUMMERS (asummers@uci.edu) is an associate professor of bioengineering and of ecology and evolutionary biology at the University of California, Irvine.



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AT A LOSS FOR

The Native-American language Salish–Pend d'Oreille is on the brink of disappearing. More than half the world's 6,000 languages will be gone by the end of the century.

By Sarah Grey Thomason

John Peter Paul, a rugged, dignified man, was extremely ill during the summer of 2000. He was ninety-one years old and suffering from stomach cancer. Still, every week he insisted on wheeling himself into the *Usšnétxw* (Longhouse) on the Flathead reservation in northwestern Montana. There, he and other elders of the Salish and Pend d'Oreille tribes would gather in meetings I had set up to expand and fine-tune the dictionary of their language and the collection of texts that we had been working on together for many years.

On one occasion in midsummer, when John's illness reached a crisis point, he refused to go to the hospital because he didn't want to miss our scheduled meeting the next day. As a result, he had to be rushed to the hospital in desperate condition the next morning. His fierce dedication to the task of documenting and preserving his language almost cost him his life.

Other elders I work with share his dedication to their language and the culture it expresses. Some are Pend d'Oreilles, like John; the rest are Bitterroot Salish (also called Flatheads). Although they are different tribes, they share the same language—which is called, logically enough, Salish–Pend d'Oreille—albeit with minor dialect differences.

But like so many indigenous languages on every populated continent, Salish–Pend d'Oreille is on the point of vanishing. Fewer than thirty fluent native speakers remain, and nearly all of them are elderly. The great majority of the roughly 6,000 Salish and Pend d'Oreille tribal members do not speak their ancestral language at all.

Flathead River area in Montana where the Hell Gate Treaty of 1855 established a reservation for the Native American Pend d'Oreille, Salish, and Kootenai tribes. The Pend d'Oreilles had lived in this area for thousands of years; the Salish originally lived farther south.

WORDS

The fluent Salish–Pend d’Oreille speakers who work with me report that the only opportunities they have to “talk Indian” are at the tribes’ Culture Committee’s weekly elders’ meetings from the fall through the spring, and in their weekly language sessions with me during the summer. John Peter Paul, who died in 2001 at the age of ninety-two, was married to his wife Agnes PokerJim Paul, a Bitterroot Salish, for seventy-two years; they were the last married couple who spoke their language regularly at home. Their oldest daughter, Josephine Quequesah, is a fluent and highly skilled speaker of the language, but some of her younger siblings have a more passive level of fluency.

What happened to bring Salish–Pend d’Oreille to this precarious position? The obvious answer—the absolute necessity for most Americans to speak English in order to survive economically, together with the appeal of mainstream American culture to most younger tribal members—tells only part of the story. Another factor is the boarding schools that many Native children were forced to attend, starting in the nineteenth century. Those schools implemented the United States government’s policy of assimilating Indians by replacing their



Salishan languages, twenty-three in all, were widely spoken in the Pacific Northwest before Whites arrived in force in the 1800s. The Salish and Pend d’Oreille tribes were allies of the neighboring Nez Perce and Kootenai tribes, and enemies of the Blackfeet.



Pend d'Oreille elder John Peter Paul (1909–2001) stands near the spot in Montana's upper Bitterroot Valley where the Salish tribe first encountered the Lewis and Clark expedition. Paul and his wife Agnes were the last married couple to regularly speak Salish–Pend d'Oreille at home.



native cultures, including their languages, with Anglo culture and English. (The policy had close parallels in Canada and Australia.)

THE ASSIMILATION POLICIES THAT took place on the Flat-head reservation—and elsewhere—were often brutal. Some teachers and principals beat children for speaking their language anywhere on the school grounds.

Louis Adams, a Bitterroot Salish elder in his late seventies, recounts what happened to him in the first grade, in a public school on the reservation. He and his friend Peter Pierre were talking Indian in the hallway of the school; a teacher heard them and broke her yardstick over Peter's head, then hit Louis with the biggest of the broken pieces. Next she took them to the principal, who said that if they spoke Indian again, he'd whip them with his belt. Louis complained to his father about the treatment and was told that he should do what the teachers wanted in school, but go on talking Salish outside of school. "Don't throw away your language," his father told him. Louis didn't, but many of his peers did.

The policy encouraged tribal members to suppress their own language. Harriet Whitworth, a Bitterroot Salish woman now in her late eighties, who—like all the remaining fluent speakers of Salish–Pend d'Oreille—has native-speaker fluency in both English and Salish, once told me she raised her five children to speak only English: "I didn't want my kids to go through what I went through." I asked whether she'd do things differently if she had known then that her language was in grave danger of vanishing forever: "Yes," she told me. "But it's too late now."

The circumstances that brought Salish–Pend d'Oreille to the brink of extinction differ from the stories of other

communities only in the details. All dwindling languages fight against time in the face of increasing pressures to speak a dominant language. English, Spanish, French, Portuguese, Arabic, Russian, Mandarin, Quechua (before the Inca Empire was destroyed by invading Spaniards), and other expanding languages have all been spoken by powerful outsiders who imposed their own order and language on subjugated, or at least less powerful, peoples. Two obvious questions arise here: Just how widespread is the phenomenon of language loss? And, more fundamentally, so what?

Before answering those questions, let me clarify that when linguists talk about language death, we are not referring to languages like Latin. Latin certainly qualifies as a dead language, but it did not die by losing all its speakers to another language; instead, it evolved into a sizable group of descendants, the modern Romance languages, almost all of which still thrive. The vanishing languages that I'm talking about leave no descendants.

Estimates of the number of threatened languages vary. About 6,000 languages are spoken in the world today. Pessimists like the linguist Michael Krauss of the University of Alaska Fairbanks predict that 90 percent of them will be dead by the end of this century; optimists predict the demise of only about 60 percent by then. Either way, we are looking at a future of catastrophic language loss.

There are, of course, quite a few languages that are certainly not going to vanish in the foreseeable future: all the languages listed above except Quechua are safe, for instance. Millions of people speak those languages, many of which are official in one or more nations. In fact, among the 200 or so nations in the world, English ranks as the most popular official tongue, cited in fifty-two

The principal told the two first graders that if they “spoke Indian” again, he’d whip them with his belt.

countries (not counting the United States, which stands nearly alone in having no official language). French follows, official in twenty-nine countries; Arabic and Spanish are tied, each with twenty-four; and Portuguese has eight countries that recognize it as official. Do the math. The count for those five languages totals 137 nations—a great majority of the world’s languages.

One might assume that other languages with at least a million speakers should also be safe, but that’s not necessarily so. Quechua, with several million speakers and official-language status in Bolivia and Peru, is steadily losing ground to Spanish, which is also official in both countries. If that is so, consider the plight of “smaller” languages, those with only 100 to 10,000 speakers—

sands. One recurrent argument, voiced loudly by proponents of the “English Only” and “Official English” movements in the U.S., is that reducing the number of languages will promote understanding and therefore national (and, ultimately, world) peace. It’s hard to take this argument seriously in a country that fought both a Revolution and a Civil War in which both sides spoke English, and in an era when Sunni and Shiite Iraqis, all speakers of Arabic, are killing each other by the hundreds almost daily.

Another common argument claims that English (or Arabic, or Spanish, or French, or Mandarin, or . . .) enables you to communicate anything you might want to say. According to that view, the loss of a language can be



Salish enduring forced removal from the Bitterroot Valley in Montana in 1891 by the United States government, which enacted the policy to open the entire valley to white settlement.

nearly half the languages in the world. Only the most isolated can be considered stable in their communities. But geographic and social isolation is itself vanishing fast, in every part of the world.

DOES LOSING A LANGUAGE matter so much? Some people favor moving toward one world language, or at least toward a drastic reduction in the cacophony of thou-

compared to the disappearance of the type of frigate that dominated Western navies in the eighteenth and early nineteenth centuries: the sailors who had mastered the intricate manipulations of the sails surely mourned their loss, but the need for effective fighting vessels made it inevitable that technological progress would sweep the sails away.

I believe, along with most other linguists and a great

many minority language communities all over the world, that any such comparison fails. Sure, tearing down language barriers would streamline international business and tourism. But a language cannot be evaluated solely on grounds of efficiency. In a very real sense, you cannot say anything you want in any language. This is not a question of translatability—of course it's possible to translate sentences like "Please pass the salt" into any language in the world—but of less tangible things, such as cultural ties, through language, to one's great-grandparents and to traditional ethnic ways of thinking about the world. Languages place special emphases on things and concepts that are important to their speakers: shapes of objects, meanings of certain plants and animals, fundamental ways of seeing the world. For instance, the word for "automobile" in Salish-Pend d'Oreille, *p'ip'úyśn*, is named for the appearance of tire tracks—literally, "it has wrinkled feet"!

Most Americans who have spoken English all their lives, and whose parents and grandparents also speak (or spoke) English, may find it hard to understand how a heritage language could matter so much. I got my first inkling of its importance when, right after college, I spent a year in Germany, speaking German constantly and becoming fluent. Although I was delighted with my new linguistic skill, I spent the whole year with the uncomfortable feeling that I wasn't quite the same person as when I was speaking English. It felt like a slight personality transplant, with different rhythms of thought and speech. I was glad to return to my English-speaking self when the year ended. This sort of discomfort must have a far more profound effect on people like the elders who grew up speaking Salish-Pend d'Oreille, but have had no chance to use it regularly for decades. And the elders I've talked to feel their own loss, and their community's loss, acutely.

In addition to the profound loss to the community, every language that dies without being thoroughly documented and analyzed robs us of potential insights into human linguistic capabilities, and reduces our chances of arriving at a comprehensive understanding of the workings of the human mind. That may sound grandiose—

after all, even if upwards of 60 percent of the world's languages vanish during this century, we'll still have a couple of thousand left, and besides, scholars have other tools for figuring out how the mind works. But there's a lot to the old notions that language is what makes us human and that its structures open a window into the mind.

The variation in human languages is not infinite. The fact that any human baby can learn any human language with equal ease is evidence of a fundamental similarity in all our languages. Nevertheless, the amount of variation is immense, and our understanding of the range and details of such variation can help challenge our theories about the nature of human language.

Even with the growing popularity of Chinese, Japanese, and Arabic, most foreign-language study in the West involves familiar European languages. English, French, Spanish, German, Italian, Russian, and Portuguese all belong to just one of the world's hundreds of language families, the Indo-European family. As a result, they share numerous structures in their grammar, sound systems, and ways of organizing their vocabularies. Studying an unrelated language is an eye-opener: it's not just a matter of memorizing a lot of new words and learning how to fit relatively familiar pronunciations and grammatical patterns into new configurations. Languages outside the Indo-European family are different in ways you can't imagine until you experience them.

SALISH-PEND D'OREILLE SURPRISES me every summer. It includes sounds that are rarely heard in Indo-European lan-

guages: stops produced with a glottal catch, sounds produced with the air sliding noisily past the sides of the tongue (lateral fricatives), sounds pronounced far back in the pharynx (pharyngeal consonants). The alphabet used to spell the language therefore contains letters that look very different from English letters, as the following examples illustrate. The language has no detectable limits on the number of consonants that can occur in a row, so that there are marvelous words like *Ta qesm'l'm'él'čstmstx^w* ("Don't play with it!"), with eight consonants in a row at the end, and *sx^wčšt'sqá* ("someone whose job it is to take care of livestock"), with seven consonants at the begin-



Elders such as Johnny Arlee (standing) who try to pass down the Salish language to the next generation face an uphill battle. But some younger Salish, including Chaney Bell (seated, center), have embraced this mission; in fact, Bell named his son the Salish word for "Whirlwind."

ning. It has words as long as your tongue, for instance *qʷo qł-č-taxʷl-m-nt-sút-m-nt-m* (“he would come up to me”). The short word, *qʷo*, means “me;” the long word has a root, *taxʷl* “start,” preceded by two prefixes and followed by six suffixes, some of them repeated. Words in Indo-European languages don’t have anything approaching this exuberant deployment of prefixes and suffixes.

Salish makes subtle distinctions that would require much more verbiage if expressed in an Indo-European language. Both *čłpntés* and *čłpntém* mean “s/he hunted it,” for instance, but the verb ending in *-és* indicates that the hunter is the most prominent character in the narrative, whereas the verb ending in *-ém* indicates that some character other than the hunter—maybe the hunted creature—is more prominent than the hunter in this context. It’s not that this distinction can’t be expressed in English or any other Indo-European language; of course it can. But not as easily, and such specificity certainly isn’t obligatory in Western languages, as it is in Salish–Pend d’Oreille. Storytellers often used this grammatical distinction to signal a subtle shift of attention from one character to another.

But like other aspects of Salish–Pend d’Oreille culture, some of the most “exotic” features of the language are fading: the last native speakers all speak English much more often than they speak Salish–Pend d’Oreille. To give one example of the effect that has on sound systems, only about three or four of the elders I work with pronounce clear pharyngeal consonants.

And in some semantic domains, most strikingly in the area of kinship categories and terminology, the much simpler English system has replaced much of the elaborate native Salish–Pend d’Oreille system. In my most recent session with the elders, in the summer of 2007, I wanted to find out how many of the old kinship terms are recognized by the current generation of elders. The kinship terms were compiled in 1976 with the help of a group of elders who are all now deceased.

At first the current group of elders said that they had never learned the old words; but the more they talked about their extended families, the more words they remembered. Dolly Linsebigler mentioned her father’s brother: she always called him her *smamáʔ*, but “after my dad died, everything changed—then he was my *łwéstn* (“aunt or uncle after the death of the connecting relative”). Josephine Quequesah remembered a word, *sméʔet*, that meant either uncle or nephew, and then Louis thought of another reciprocal kin term: “Yeah, like my *t’ot’ó* used to call me her *t’ot’ó* (“great-grandparent or great-grandchild”).

Dolly also commented that people who come from big families like hers got used to all the complicated terms, like *łqáqceʔ* (“woman’s older brother”), *q’eʔéw’s* (“middle brother”), and *śśn’ceʔ* (“woman’s younger brother”). But many words were already beyond their memories, unrecognized. Like other complex systems of kin terms

around the world, Salish–Pend d’Oreille offers insights into the possible range of categories for human relationships. But the old system teeters on the brink of oblivion, and the same is true of intricate kinship systems all over the world.

Within the next twenty or thirty years, there will be no speakers left who learned Salish–Pend d’Oreille as a first language, spoke it regularly in their younger years, and revisited it throughout their lives. There are twenty-two other languages in the Salishan family, and they await the same sad fate. When there are no longer any Salishan speakers who remember how their grandparents and great-grandparents spoke, the old kin terms will vanish, along with the other cultural and historical riches encoded in the ancestral languages.

Language death, much too much language death, seems inevitable in this and future decades. But the picture is not completely dark. Many communities whose languages are threatened, including the Salish–Pend d’Oreille tribes, have begun vigorous efforts to document and revitalize their languages, so that today’s and tomorrow’s children will be able to learn them. In a few spectacular recent cases, notably Maori in New Zealand and Hawaiian in the U.S., heritage languages have been restored to the community’s children. And in perhaps the most dramatic historical case, Modern Hebrew emerged as the native language of a new nation’s children after 2,000 years of near-death.

Even when efforts to save heritage languages fail, that doesn’t mean the effort has been wasted. If fluent native speakers help document a dying language, with a full grammatical description, a dictionary, and a collection of narratives, the possibility of revival will always be there. The revived version won’t match the earlier version, but it can still serve its community. It can allow traditional practices and values to be expressed without the disruptions of translation, making the past more accessible. It can contribute its unique data to the scientific understanding of the universal human capacity for language.

Ultimately, though, if a community loses its language as its main vehicle of communication, both the community and its individual members lose an irreplaceable part of their identity. And at the same time, a part of our common world that their language uniquely illuminated goes dark.

Sarah Grey Thomason

Thomason has worked with the Salish–Pend d’Oreille Culture Committee since 1981, compiling a dictionary and text collection in collaboration with tribal elders. Thomason, who is currently co-authoring a textbook on endangered languages for Cambridge University Press, is the William J. Gedney Collegiate Professor of Linguistics at the University of Michigan and is a former president of the Society for the Study of the Indigenous Languages of the Americas.



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TRACES IN THE SAND



**LIBYA BOASTS ANCIENT RUINS BUILT OVER THE CENTURIES BY BERBERS,
PHOENICIANS, GREEKS, ROMANS, AND ARABS.**

Photographs by Ellen Kaplowitz ~ Text by Mary Knight



A Natural History Photo Essay

Long before it was dominated by sand and oil wells, Libya hosted a diverse fauna that feasted in its fertile green valleys. Such natural resources in turn lured prehistoric human populations more than 10,000 years ago. The climate became increasingly arid, though, and within a few thousand years the region's inhabitants were congregating on the more hospitable shores of the Mediterranean. The indigenous peoples—speakers of Berber languages primarily—were later joined by waves of colonists from abroad: first Phoenicians, around 1000 B.C., from what is now Lebanon and Syria, and then Greeks, Romans, and finally Arabs. For all those who claimed portions of Libya, the scarcity of water posed a challenge.

The historian Herodotus, writing in the fifth century B.C., tells the story of the founding of the first Greek colony in Libya: The king of the island of Thera complained to the oracle at Delphi that his land was without water. The priestess advised him to “colonize Libya.” Of course, the irony of this advice (to emigrate to a permanently dry place from one in a temporary drought) was lost on the Greeks of the time. But colonize Libya they did. And ultimately, the Greek city of Cyrene became famous for its philosophers and mathematicians. Oddly enough, its wealth grew from the region's production of silphion, a now extinct plant, which caused abortion—much like an ancient version of “Plan B.”

Romans settled primarily in the west, in Tripolitania, the “land of three cities”: Sabratha, Oea (modern Tripoli), and Leptis Magna. All three were originally Phoenician trading outposts, but the Romans outfitted them in style for a king, Septimius Severus (ruled A.D. 193–211), who hailed from Libya. By the fourth century, his cities had begun to fall to ruin, plundered by lawless bands and prolonged droughts. As ruins go, however, the beaux arts of his time are remarkably well preserved.

The Islamic “opening up” (*al-fath al-islamiya*) of the region west of Arabia, beginning in 643, brought a new style of architecture specially adapted to the desert. The Arab mud-brick structures were painted white, for instance, to reflect sunlight, and their thick walls and high ceilings kept their inhabitants cool.

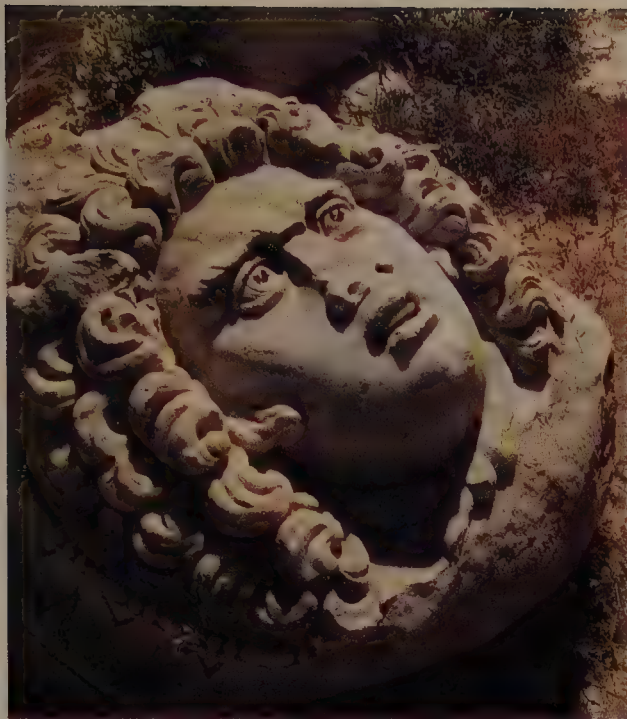
Libya's natural resources, particularly its oil, continue to draw people and nations from around the world into its economic orbit. Twenty years of trade sanctions have arguably overshadowed the region's past. But its ancient ruins, largely obscure to Western travelers, may still stand out to archaeologists a thousand years from now—long after today's conflicts have been forgotten.



Mud-daubed walkway in Ghadames, opposite page, allows residents to stay cool in the hostile Saharan heat. Occupied for centuries by Romans, Ghadames operated as a trading town and remains inhabited today. Above: a panpiper from a marble pilaster in the apse of the Severan Basilica of Leptis Magna reflects the city's Roman roots. Left: the Roman-era theater at Sabratha, a city founded by Phoenician colonists.



Severan Basilica (built under the rule of Septimius Severus), above, viewed through fallen colonnades, stood at the head of the central road leading through the city of Leptis Magna. Opposite page: other ruins at Leptis include a gorgon head—one of many decorating the arcade of Severus, top middle; marble latrines in the great Roman baths, top right; and an open-air theater, middle. Bottom of opposite page: portions of the “labyrinth mosaic” of the house of Jason Magnus, a wealthy citizen of Cyrene, reveal that the opulence of that city, founded by Greeks, continued into the Roman period.

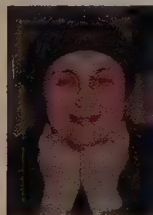




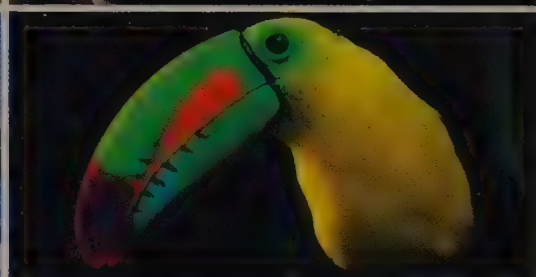
Granary, above, was built some 700 years ago in the Berber town of Nalut, which sits high above the surrounding desert. Locals call the structure a *gasr* ("castle"), but the rooms were simple storage facilities used by local families for grain and oil. A high exterior wall (not shown) protected the granary from attack as well as from the ravages of sand and wind. Left: Berber messages imprinted on stone by Saharan nomads may date from ancient times or from yesterday.

Ellen Kaplowitz and Mary Knight

Ellen Kaplowitz's images have appeared at a number of museums, including the Field Museum in Chicago and the American Museum of Natural History in New York, and in her most recent book, *A World of Decent Dreams: Vietnam Images* (Weatherhill Press, 2003). Visit www.ellenkaplowitzphotography.com for more. Mary Knight is currently a visiting scholar at New York University and a member of the Cyrenaica Archaeological Project. She has spent much of the past decade working in and traveling throughout North Africa.



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BABOON HEAVEN

A SOUTH AFRICAN ANIMAL REHABILITATION CENTER GIVES AN UNPOPULAR PRIMATE TLC AND A CHANCE TO RETURN TO THE WILD.

BY MICHAEL C. BLUMENTHAL
PHOTOGRAPHS BY ATTIE GERBER

HOW DID I GET HERE, WITH DENNIS HUDDLED AGAINST MY CHEST, TORTILLA GROOMING THE HAIRS ON MY ARMS, SABRINA ON MY LEFT SHOULDER, AND MAGGIE ATOP MY HEAD, BEHAVING LIKE A HAIRDRESSER? AS I SMACK MY LIPS IN AN ATTEMPT TO MIMIC MY COMPANIONS'

grunts and chatterings, Sinamo does a backward somersault between my legs, chasing after Cory and Jagger.

Friends and colleagues, perhaps secretly envious, have predicted that as a city boy and literature professor, I would feel out of place among these orphaned chacma baboons. Yet here I am, on the bank of the Olifants River in South Africa, yards away from wild crocodiles and elephants and hippos and the occasional lion. And it feels good—this grooming and chattering, these small baboon bodies hunkering against my chest.

THIS IS THE BABOONS' STORY, not a woman's, yet it must begin with a woman nonetheless—for it is with her that it all began. Rita Neumann was in love with animals as early as she can remember. Born in 1931 in Germany, she dreamed of becoming a veterinarian, but that path was closed to her because higher educational institutions granted preferential admission to soldiers returning from the Second World War. Rita went to work instead at Hamburg's renowned Hagenbeck Zoo and then, in 1953, emigrated to Johannesburg, South Africa. There she soon married her German fiancé, Lothar Simon, and the couple had a daughter. In 1963 Rita bought a fifty-acre tract of bush wilderness near Phalaborwa, about 250 miles northeast of Johannesburg, that was destined to become her intimate link with the animal life she loved. But before that, in 1972, tragedy struck: Rita's husband and their seventeen-year-old daughter were both killed in a small-plane crash.

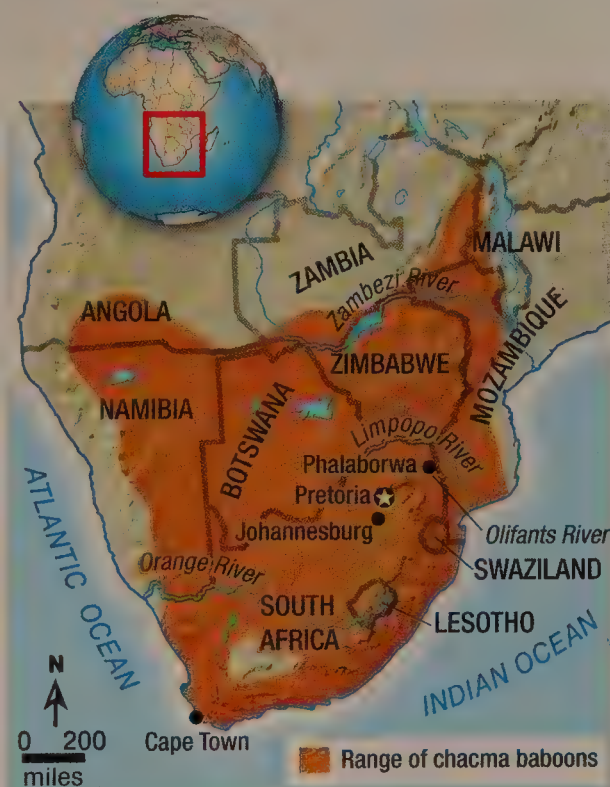
Eight years after the accident, during her brief second marriage to Piet Miljo, an Afrikaner, Rita made what might be regarded as the transforming acquaintance of her life. While traveling in

northern Namibia, she encountered a baby female chacma baboon named Bobby. (In fact almost all anonymous baboons in South Africa were dubbed Bobby, after the Afrikaans name for the species, *bobbejaan*.) The animal had been plied with alcohol and abandoned in a trash bin at a military encampment. In defiance of the requirement for permits, Rita took Bobby home, and a bond between baboon and human was forged. In 1989, along with Bennett Serane, a like minded South African, Rita founded the Centre for Animal Rehabilitation and Education (C.A.R.E.), and her fifty acres of bushland became a refuge where injured wild animals—various birds, reptiles, and small mammals, initially—were treated and released.

As increasing numbers of injured or abused chacma baboons, mostly orphaned babies, were brought in, the center began to specialize. Agricultural lands had encroached on the baboons' natural habitat, and wherever crops were threatened, farmers had the right to shoot the offending "vermin." Poaching, poisoning, illegal trade in pets and experimental animals, as well as environmental hazards (natural or otherwise), also left behind baboons in need of C.A.R.E.

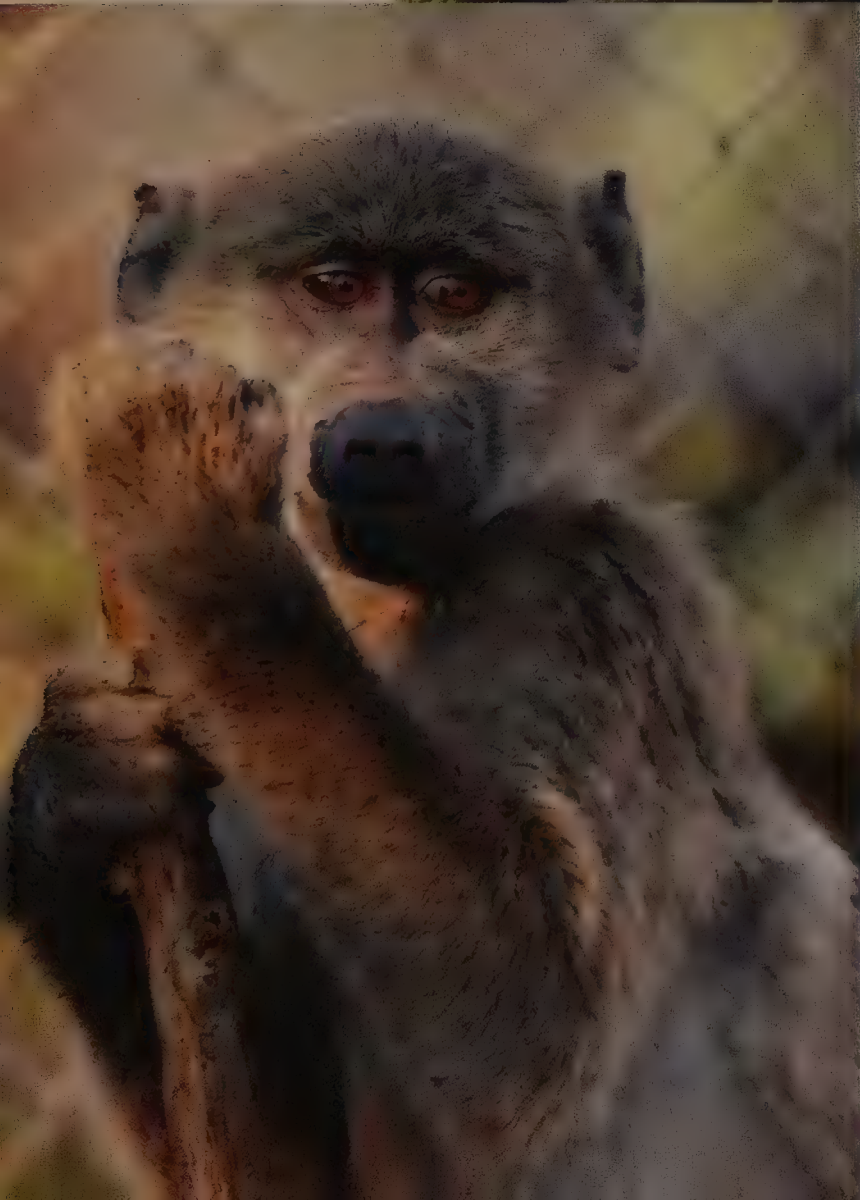
"You know, they are the last creatures under the sun that nobody cares about," Rita says. "When I first started, everybody said to me, 'With all that energy you've got, why don't you look after rhinos?'—or cheetahs, or whatever else it was they cared about. And I answered, 'Because these guys need me.'"

Stefan, about one year old in photograph on opposite page, was born within a chacma baboon troop made up of animals rescued by the Centre for Animal Rehabilitation and Education (C.A.R.E.). Located near Phalaborwa, map above, C.A.R.E. attracts volunteers to act as foster parents for its young orphans and to perform many other duties.



THESE GUYS DO NEED HER, as I quickly find out when I arrive in May (South African autumn) to serve as a C.A.R.E. volunteer for three weeks. At the Phalaborwa airport I am picked up by the Centre's manager, thirty-eight-year-old Lee Dekker, a cheerful woman who exudes an air of commitment and competence. Normally she would be carrying an infant baboon in a shawl tied around her waist, but today the only baboon she's wearing is the one imprinted on her T-shirt. Since she has to stop in town

Stefan pictured at about two weeks of age, right, with his mother, Schatzi, and other female members of his troop. Known as Tito's Troop for its alpha male, the troop was released on farmland but had to be relocated when landowners began to exercise their right to kill "vermin." Below: Baboon that, when an at-risk infant, was transported by C.A.R.E.'s director, Rita Miljo, without the required permit. He was given the name James Bond because the rush rescue required a detour to avoid a roadblock. A judge acquitted Rita of wrongdoing on the grounds that she acted out of necessity to save the baboon.



to do some food shopping, she's left the baby she's foster-mothering, Suzie, behind.

"The situation for wildlife in Africa is essentially hopeless," Lee tells me en route, "but we keep trying." Nearing the Centre, we drive along the crocodile- and hippo-filled Olifants River—a tributary of the "great grey-green, greasy" Limpopo, of Rudyard Kipling fame, where the Elephant's Child of the *Just So Stories* got his nose stretched into a trunk by a crocodile. I see a memorial wreath along the water's edge. "Don't ever walk along the river bank by yourself at night," Lee warns me, "and, for God's sake, don't ever go swimming in it. We don't want to have to put one of these up for you."

How I got to C.A.R.E., like so many of the volunteers, is by watching the Animal Planet network—to be precise, a show called "Growing Up Baboon," featuring the work of Rita Miljo and her staff. Another volunteer, Kim Solbakk, a former real estate investment manager from California making her fourth visit in less than two years, echoes my own sentiments: "I had always been interested in primates," she says, "and I wanted to do something hands-on."

What a volunteer does have on his or her hands, almost from the moment Lee's truck pulls into the Centre, is baboons—including baboons jumping on the back of the truck to help themselves to the victuals before Lee can frighten them off with stones and pull in behind the fenced gate. You quickly learn that there are actually *two* populations of

baboons in residence—a “wild” group numbering around 120, affectionately dubbed the “Longtit troop” by Rita for reasons that take little time to become apparent, and the 300 to 500 captive baboons, whose relatively spacious metal-and wire-reinforced enclosures are dispersed all over the property. The wild baboons arrived uninvited, but their presence has had the serendipitous effect of showing that wild and caged baboons can interrelate. The younger caged baboons learn about foraging, playing, fighting, and copulating by observing and interacting with the older free ones, and—since baboons are able to figure their way around virtually any obstacle—adult members of the two groups freely copulate.

Rita and her staff’s most radical innovation over the years, however, has been the artificial formation of coherent troops that can succeed on their own in the wild. Previously it had been largely taken for granted that a troop had to form naturally, through a matrilineal lineage, with females spending their lifetimes in the same troop and a few dominant males moving in and out. But Rita discovered that by combining compatibly aged, sexed, and spirited baboons into troops within the cages, then allowing them to reach maturity, she could release them back into the wild together.

C.A.R.E.’S WEANING PROCESS ATTEMPTS to closely parallel what takes place in nature. During the first month or two, a newly arrived orphan infant spends twenty-four hours a day, seven days a week (including time in the shower and on the toilet) either tied around its surrogate mother’s waist in a shawl, or in her arms. When the surrogate mother, the staff, and Rita think the infant is ready, it is moved to the nursery with the other infants for several hours a day, returning to sleep with the mother at night. This phase slowly morphs into the next, usually at around two months, when the infant grows comfortable spending the entire day in the nursery, and only nights with its mother.

During the final phase, the most trying for the little babies, the infant continues to sleep in its surrogate mother’s room at night, but in a small cage. This prepares it for its real “move” into post-infancy, when it will begin to sleep with its contemporaries—and, of course, their stuffed animals. Those youngsters are cozily set up in the main house, in Rita’s bathroom.

MY SCHEDULE IS FAIRLY TYPICAL for a volunteer: from 11:00 A.M. until noon I prepare bottles from powdered milk—several hundred bottles are distributed daily; then, from 1:00 P.M. to 2:00 I play and socialize with the “mediums” (baboons between eight months and a year old); from 2:00 to 3:00, with the “smalls” (between four and eight months); and from 4:00 to 5:00, with the infants in the nursery. At around 5:30—it gets dark early—all three groups of babies are brought indoors to spend the night.

In the mediums’ cage I have my first exposure to being

mobbed by a group of frightened baboons. There are seventeen of them, ten females and seven males. Dennis, one of the lower-ranking males, quickly decides I’m a threat. Just when I think we’re beginning to develop a rather friendly, if cautious, relationship, something I do—perhaps an inadvertently raised eyebrow, or a set of teeth too conspicuously revealed—triggers his anxiety and, before I know it, a high-pitched warning cry issues from his lips. In seconds, all seventeen of the mediums, teeth bared, make for my calves, my arms, my thighs, my waist.

Ah! Ah! Ah! cries Zurika Potgieter, who along with Elena Pasotti supervises the volunteers, mimicking the



Rita acts as foster mother for an abnormally small female baby. The infant was the first-born of a very young female, and under natural circumstances most likely would not have survived.

baboon cry that means “Cut that out!” She yanks several of the young tykes off me by their arms, legs, scruff of the neck, ears, and tails. (Baboons have amazing abilities to tolerate pain and to heal from injury—a baboon can be dragged, pulled, bitten, and clawed so much in the course of the average day that its very survival, much less its prospering, seems a near miracle.) Later, in the nursery cage, I also learn that baboon society is profoundly gender-

oriented, and that the animals have very discriminating eyesight. From the moment I first enter the cage, these infants know I am both a stranger and a man, and they beat a hasty retreat into Elena's already baboon-filled arms. "They just need to get used to you," she consoles me. "They're terribly afraid of new men."

A volunteer has little time to waste in learning how to navigate life among the young baboons. Once you have picked, cajoled, lifted, and forced enough of the little guys and girls from your head, thighs, shoulders, and waist to have a seat on one of the plastic crates provided for that purpose, you must wrestle with the first of many challenges about to confront you: How do you tell Dennis from Kimberly, Tortilla from Yoshi, Judy from Jagger? Everyone else seems able to do it—so why not you?

The male/female bit is easy enough. If you can't stop them moving long enough to spot a penis, or lack of one, there's another simple method: in males, the callosities, or buttocks, are fused below the anus; in females, they are conveniently separated to make room for the sexual organs. And then, slowly but surely, you become aware of more subtle differences: Kimberly has rough, thick gray fur and—with the exception of Sinamo, the alpha female—is the largest of the troop; Icarus has several scar markings on his left cheek; Maggie is not only nearly inseparable from her brother, Dennis, but is also missing her tail; Cory is the one who attempts to masturbate on your left knee. After a few weeks of this, you could swear your eyes are becoming as focused and discriminating as the baboons'!

ONE OF THE OTHER THINGS you need to learn quickly is baboon language: lip-smacking, grunting, warning calls, laughing sounds, mating cries—the emotional range is rather astonishing. I've already become acquainted with the warning cry—and its repercussions—thanks to Dennis. In the meantime, I arduously practice my lip-smacking, the ultimate accompaniment to the come-hither face, in front of the mirror. My attempts more closely resemble a forlorn lover blowing kisses than a baboon trying to be friends, but I'm just a beginner, after all.

"You can pick your friends and you can pick your nose, but you can't pick your friend's nose," was a popular elementary school joke when I was growing up in Manhattan, but it certainly isn't the prevailing ethos here. Maggie, who is clearly becoming my friend, is not at all averse to picking at my nose, my ears, my eyelids, my lips, and my gums, as well as virtually any other protrusion or orifice her adept little hands can reach.

In the nursery one afternoon, I meet Shanti, a two-month-old female who greets me with a flattering, and utterly archetypal, gesture: the presentation of her *derrière*. The presenting of the female buttocks, in the hope that the one so honored will comply by scratching them, is a gesture of incipient friendship and interest (it can also have



other functions, such as expressing a desire for grooming or copulation, or surrender after a fight). So I scratch, and Shanti, temporarily satisfied, scoots off playfully into Elena's arms.

Shanti's story—heartbreaking, but not uncharacteristic of orphans who have the good fortune to end up at C.A.R.E.—is that her previous owner had nourished her largely on alcohol, a substance infant baboons will ingest all too readily. Within days of her arrival at C.A.R.E., it became clear that poor Shanti was going through detox. Originally Lee's baby, she also takes a liking to one of the volunteers, Jacob, who agrees to take on the rather unique status of being a male "stepmother" until his departure.

TO SAY THAT BABOONS ARE not earth's most beloved creatures is to establish oneself as a master of the art of understatement. Not only do baboons not lend themselves to being dressed up in overalls or tutus and paraded onto the *Late Show with David Letterman*, they also, when grown, have an elongated snout, reminiscent of a dog's,



Volunteer Maria Corales and her foster "child" (in diapers), left, socialize with some young baboons. At first infants are carried by their foster mothers twenty-four hours a day, but then are gradually weaned. Top photo: Young baboons play on a tree used as the sleeping place of Tito's Troop. Above: members of the troop before they had to be relocated.

not the relatively flat, humanlike face of a chimpanzee. Contemporary folk tales in Africa and elsewhere freely portray baboons as stupid and lazy. And in South Africa, where people once received a monetary reward if they could hand in a baboon scalp and tail, all sorts of unflattering myths endure.

Nor are baboons in general especially endangered primates. But as Rita says, "Why do we have to wait until the baboons are almost extinct until we care for them?" In any case, the loss of any regional population can be significant. By one reckoning all baboons belong to the same species, *Papio hamadryas*, and the chacma baboon, *P. h. ursinus*, is one of five subspecies. Even within that subspecies, two or three forms can be distinguished: the Cape chacma, the gray-footed chacma, and perhaps the Ruacana chacma.

The potential for future tragedy motivates Rita and the staff not only to nurture the orphans in their care, but also to return animals to the wild. In the nearly twenty years of C.A.R.E.'s operation, some eight troops totaling roughly 150 baboons have been released all around South Africa. The process is time-consuming and complex. Not only must an appropriate release site be located, permits applied for, and the troop transported, but also two "release managers" (one of whom needs to have bonded tightly with the troop's alpha males) must accompany the troop to make sure the animals can successfully forage on their own. The release managers select a sleeping tree as a central gathering place, sleep at the site, and lead the baboons to water, fruiting trees, and other resources until the males are able to find them on their own. One of the managers may have to remain with them for as long as five months.

During my stay as a volunteer, a troop is being readied for release. The same troop was released once before, five years ago, and survived two years on land owned by a sympathetic farmer. When a tolerant neighbor died, however, the animals fell prey to shooting and poisoning. Rita and Lee then brought them back to begin the whole process over again!

IT'S WITH DENNIS—THE "medium" whose warning cries first led to my being mobbed—that I develop my most complicated, and at times perplexing, relationship. Along with his devoted sister Maggie, my hairdresser, he spends much of the time when I'm in the cage grunting and vocalizing in my arms and grooming me to calm himself. He repeatedly comes to me for comfort, but—when I apparently don't satisfy him—begins biting me, or crying out for help.

Several days into my stay, thanks to Dennis's instigation, I get mobbed twice. My mistake: projecting human reactions onto the baboon world. I'm expecting simple gratitude—after all, who's been protecting and cuddling him these past several days?—but I've not reckoned with baboon politics. The fact is, Dennis falls very low, perhaps lowest, in the troop hierarchy, and those of low rank will often "switch sides" against a common enemy (me!) as a way of trying to ally themselves with their more powerful cohorts.

Making eye contact with me obviously frightens Dennis: whenever I look at him, or try out my lip-smacking, he runs off screaming. I decide to adopt a new strategy, which actually seems to work: I studiously look away whenever he tries to meet my gaze. I sense he is just waiting for our eyes to meet to give out the *help!* cry and have the others mob me, and I'm not buying.

The fact that your spirits rise when young baboons are nicer to you than they were the previous day may not signify that you have risen within our own not-so-humble species, but that's how I'm starting to feel. It's another day, and the mediums seem genuinely happy to see me, with Kimberly jumping down on me at least a dozen times

from the wooden post above and lying playfully in my lap, and Tortilla and Sabrina madly vying for Maggie's hairdresser role. My Dennis strategy seems to be working, too: he constantly tries to make eye contact, first from my lap and then from various vantage points around the cage, but I steadfastly hold to my resolve—stroking and lap dancing are okay; eye contact, no.

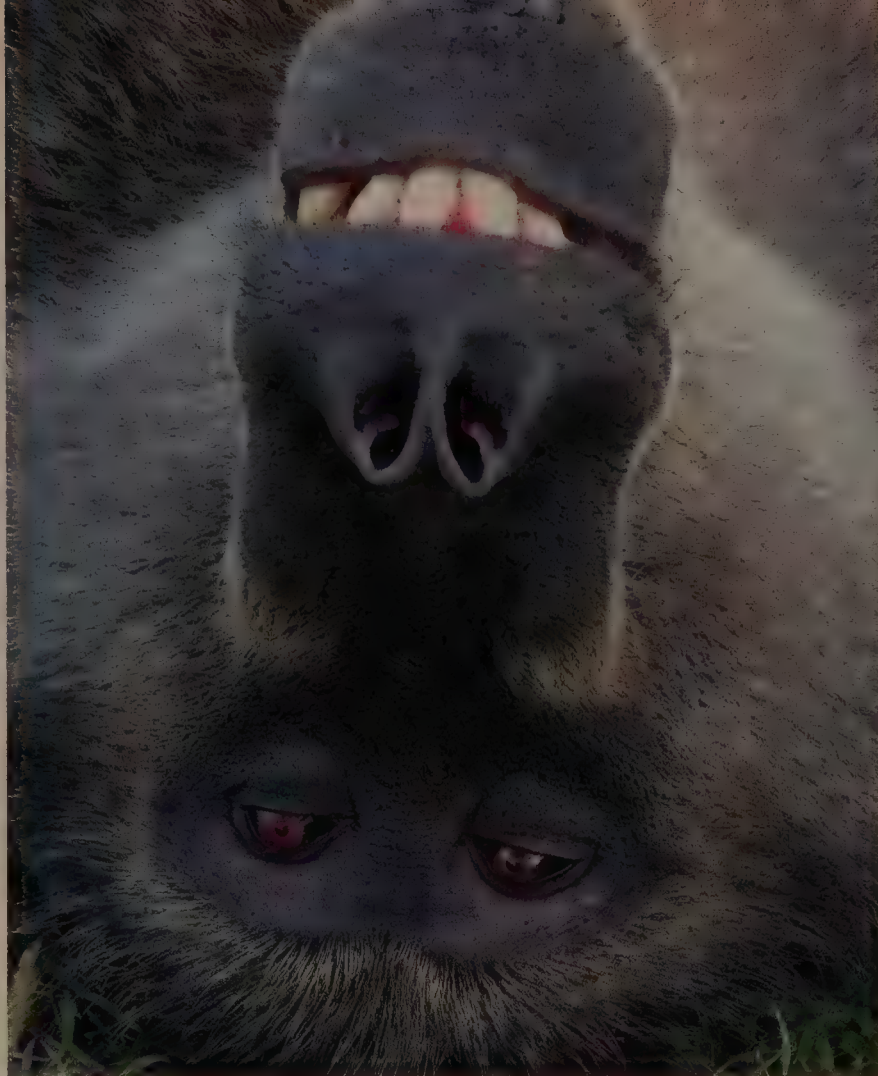
This morning, though, one of the adult baboons has been found dead. His purplish-black tongue reveals he has died of asphyxiation, the result of a black mamba bite, the deadliest snakebite of all. In the brief time since my arrival, three baboons have now died (two from snakebite, one from tetanus).

Several others have been mauled by baboons from the wild troop, reaching into the cages. Each day brings its small and large emergencies—illnesses, accidents, deaths, injuries, escapes, fights.

BY THE END OF MY SECOND week, I'm beginning to feel a bit baboony myself. It's not a bad life, being the alpha male. Somebody up there on my head—Tortilla? Sabrina?—madly grooms my hair, my eyes, then moves on to my chest and, along with periodic yanks on my chest hairs, methodically chews off all three buttons on my shirt. Then, also, there are lots of soft kisses along my eyes, nose, and ears today, not only from Maggie—who has also taken to kissing me on the lips—but from Kariba and Tortilla as well. I'm slowly fitting in, I find, just becoming another one of the family.

But before I know it, my stay at C.A.R.E. is drawing to a close. Suddenly one of those “super-emotional human things” Rita likes to speak of takes possession of me: I am actually going to have to say *good-bye* to Dennis and Maggie and the others. Sentimental to the core, I decide to put it off: I'm spending a week in Phalaborwa before my flight; I'll just come back before I leave and do the dirty work then.

On the day of my flight, I rent a car and drive back to the Centre. As soon as I arrive, I make one of those “human errors” (Rita's favorite expression) and leave my car outside the volunteer lodge, instead of locking it up behind one



Tito, the alpha male, photographed on awakening (a second later he jumped up and displayed his canine teeth in warning).

of the fences. Though I've removed any obvious sign of food, I should, after three weeks of living among my primate cousins, know better. By the time I've walked down the hill to Rita's house, the wild troop has ripped the passenger-side mirror off in search of something to eat. “Stupid baboons?” Not at all—just another example of a rather careless human.

When I walk into Rita's living room, Suzie, Lee's baby, is so glad to see me that she leaps onto the sofa to play. But there's also been bad news during the night: Nathan has died of pneumonia after eleven years at C.A.R.E. While shaving his chest to do the chest X-ray, they made a disturbing discovery: a

number had been tattooed on him by the experimental lab where he was used as a subject before Rita rescued him.

Before leaving, there's one last thing I need to do. I enter the mediums' cage, where I am immediately greeted and climbed upon by Dennis and Maggie, along with Sabrina and Tortilla. I take a seat on one of the crates, Maggie and Dennis firmly planted on my right knee as usual, Maggie fervently grooming me.

But I don't have much time for the hairdressers today; I've got a plane to catch. So I turn and look Dennis right in the eyes, lip-smacking and smiling as I do so. He looks back at me, neither running for cover nor sounding the alarm cry, lip-smacking as well.

And I could swear he is smiling too.

Michael C. Blumenthal

Formerly a New Hampshire law clerk to now-Supreme Court Justice David Souter, a science writer/editor for *Time-Life Books*, and director of creative writing at Harvard, Blumenthal occupies the Darden Endowed Chair of Creative Writing at Old Dominion University in Norfolk, Virginia. It was only in hindsight that he realized that one of his motives in experiencing and writing about C.A.R.E.'s mission may have sprung from a deeper connection with the animals: “Not only were the infant baboons separated from their mothers at birth, I was too—adopted away from my natural mother when I was eight days old.” Blumenthal's own family circumstances are recounted in his book *All My Mothers and Fathers: A Memoir* (Perennial, 2003).



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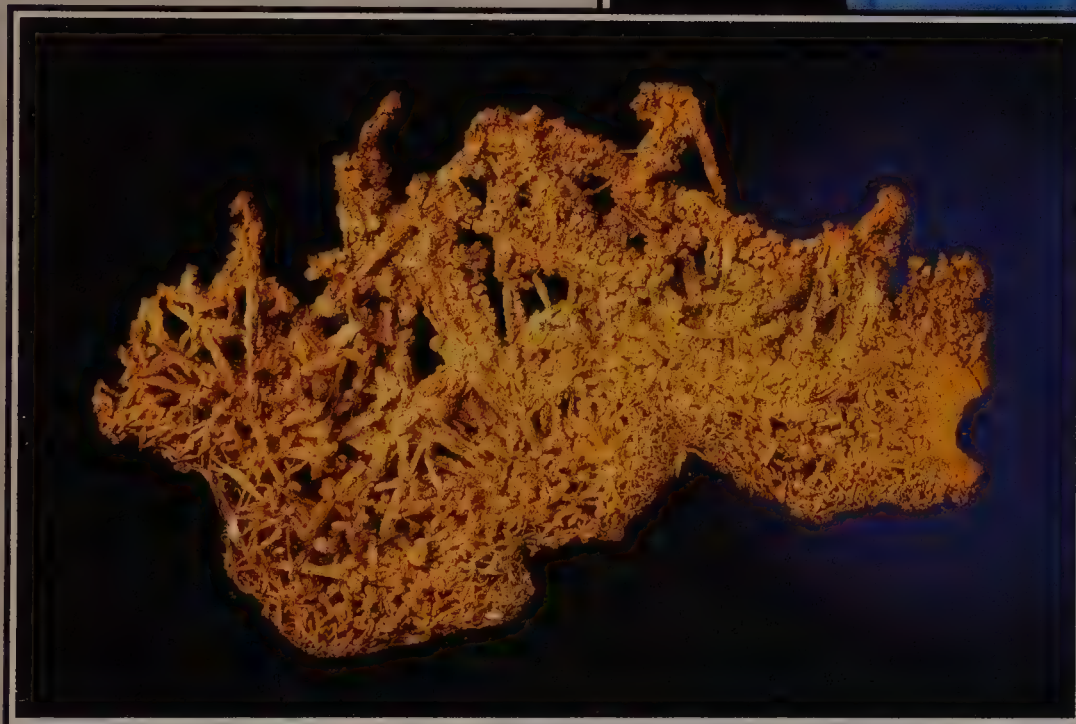
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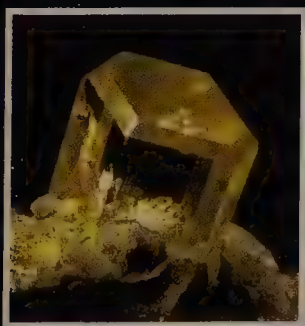


Aquamarine
Shigar Valley,
Pakistan; 7 inches



Gold, 4.2 inches
Wire Patch Mine
Breckenridge, Colorado
(mined in the 1880's)
Currently featured in
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Grotto Spring Run, sixteen miles south of Florida Caverns State Park, is one of the Chipola River's many tributaries.

Florida Underground

At a state park riddled with caves, even the Chipola River ducks below the surface.

By Robert H. Mohlenbrock

As its name implies, Florida Caverns State Park is a place to see stalactites, stalagmites, and other cave features, but it also boasts a variety of natural plant communities, including one in which Appalachian Mountain species reach their southernmost limit. The park lies about sixty-five miles northwest of Tallahassee, near the small city of Marianna, the seat of Jackson County. It covers a two-square-mile area that ranges from 65 to 180 feet above mean sea level. Flowing through it from north to south is the Chipola River, whose name is said to be Choctaw for "sweetwater." The river is eighty

feet wide in some places, but it also sinks underground for about half a mile (though some of the water flows



Southern magnolia

across the surface in a ditch cut 100 years ago for a logging run).

The park owes its geological features to a complex history. Some 300 million years ago, two primeval supercontinents, Gondwana and Laurasia—themselves the products of earlier tectonic movements—collided to form a single landmass, Pangaea. When, about 100 million years later, Pangaea began to break up, a fragment of the African continental plate remained attached to North America. That rock ultimately underlies what is now Florida and adjacent areas. During the past 100 million years, the region was often covered by the

Appalachian forest Vegetation along the Beech Magnolia Trail is reminiscent of that in the Chattahoochee National Forest of northern Georgia, with such trees as American beech, American holly, black walnut, southern magnolia, white ash, white basswood, and yellow poplar

towering over blue phlox, daisy fleabane, elephant's-foot, hairy phlox, mistflower, partridgeberry, Solomon's-seal, Virginia snakeroot, and other Appalachian wildflowers. Species just barely reaching Florida from the Appalachians are Allegheny spurge, bloodroot,

Chattahoochee River wake robin, false rue anemone, lance-leaved wake robin, mayapple, waxy meadow rue, and two very uncommon wake robins: purple toadshade (*Trillium underwoodii*) and spotted wake robin (*T. maculatum*). Species that fall between the canopy trees

and the wildflowers include bigleaf snowbell bush, needle palm, red buckeye, southern flame azalea, and sweetshrub.

Upland forest The uppermost elevations of the park, along its eastern and western sides, are relatively dry. Among

sea, which laid down layers of shells, corals, and other carbonate deposits. Those deposits eventually formed an enormous platform of limestone tens of thousands of feet thick.

Once formed, the limestone was subjected to the whims of sea-level fluctuation. When the sea level was high, acidic ground water found fissures and cracks in the soluble limestone, and slowly enlarged those



The coral snake is highly venomous.

building up residues in the form of columns, draperies, rimstone pools, soda straws, stalactites, and stalagmites. Visitors to the park may view such wonders by taking a guided tour along a lighted pathway in one cavern.

A number of underground chambers known in the park are not included in the tour. One is Salamander Pond Cave, which contains an underground pool 183 feet long, 13 feet wide, and more than 8 feet deep. Two rare cave species live in that aquatic cavern, the Dougherty Plain cave crayfish (*Cambarus cryptodytes*) and the Georgia blind salamander (*Haideotriton wallacei*).

Geological activity has hardly ground to a halt in the region. The Chipola River continues to erode the limestone; the River Sink is where the river disappears about 100 feet below ground before emerging downstream. Blue Hole Spring, a pool nearly 100 feet in diameter and 39 feet deep, is fed by an artesian spring, where water emerges under pressure at a rate that has been measured at 56.8 cubic feet per second. The overflow creates picturesque Carter's Mill Branch, which eventually flows into the Chipola River.

The Chipola is a small tributary of the Apalachicola River, which originates to the east of the park as a confluence of the Chattahoochee

and Flint rivers. The Chattahoochee has its headwaters in the mountains of northern Georgia, and this connection has provided a pathway for plant species of the Appalachians to

migrate into northern Florida. The park's trails, including the Beech Magnolia Trail and the Bluff-Floodplain Trail, provide a cross-section of the vegetation. If you hike in the park, be aware that alligators, coral snakes, cottonmouths, dusky pygmy rattlesnakes, eastern diamondback rattlesnakes, and snapping turtles live there as well.

ROBERT H. MOHLENBROCK is distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.



VISITOR INFORMATION

Florida Caverns State Park
3345 Caverns Road
Marianna, FL 32446
850-482-9598
www.floridastateparks.org/floridacaverns/

pathways into caverns channeling underground streams. When the sea level and water table fell, the caverns drained, and in the presence of air, calcium carbonate that was dissolved in dripping water precipitated out,

the trees flourishing here are flowering dogwood, hop hornbeam, laurel cherry, laurel oak, live oak, loblolly pine, and spruce pine.

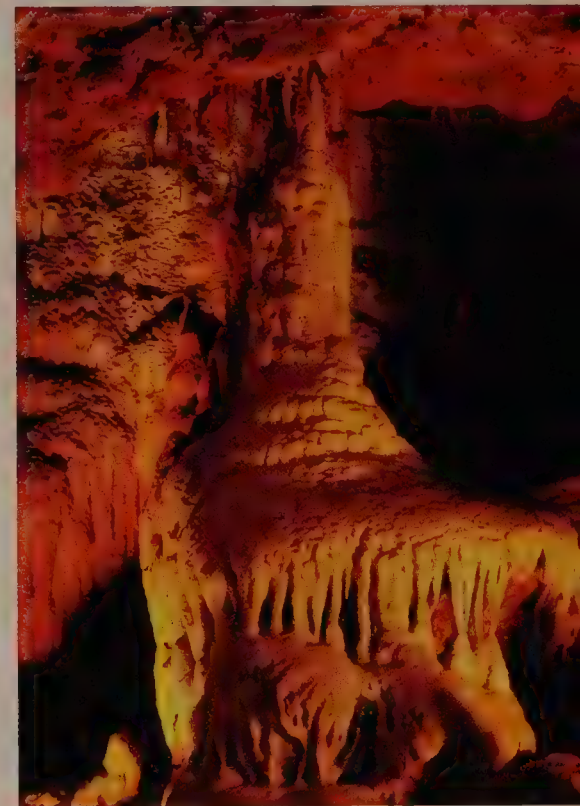
Floodplain forest The fairly flat and low-lying terrain that borders the Chipola River and its tributaries is inundated

each year when the river and streams overflow. Trees that inhabit the wettest areas include American hornbeam (also known as musclewood), bald cypress, green ash, loblolly bay, Ogeechee lime, overcup oak, swamp gum, sweet bay, tupelo gum, water hickory, and water locust.

Bluestem palmetto is plentiful beneath the trees.

Limestone cliff Low limestone cliffs, up to thirty feet tall, appear in places along the Chipola River. False rue anemone and wild columbine are common, growing from crevices in the cliff face. A

close examination of the cliff face reveals bicolored spleenwort, ebony spleenwort, modest spleenwort, and Morzenti's spleenwort, the rare one-sorus spleenwort, and southern maidenhair fern. The attractive oak-leaf hydrangea hangs from the tops of the cliffs.



"Wedding cake" dripstone formation in the cavern

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Best Books for Young Readers, 2007

By Diana Lutz

FOR BEGINNING READERS

Owen & Mzee: The Language of Friendship, told by Isabella Hatkoff, Craig Hatkoff, and Dr. Paula Kahumbu; photographs by Peter Greste (Scholastic Press; \$16.99)

This tender photo-essay, a sequel, chronicles the unlikely friendship that began when a baby hippo, Owen, orphaned by the terrible tsunami of 2004, was taken to the Kenyan wildlife sanctuary where a 130-year-old tortoise, Mzee, was living. Since the last book, the two friends have worked out a "language" of their own. Owen has learned to steer the tortoise by nipping or nuzzling a hind leg; Mzee blocks Owen's way when the hippo gets upset and prepares to charge.

Both speak in a grunt unknown to either hippos or tortoises in the wild.

At least six illustrated books by various authors have covered the pair's story, a natural for children.

But this team—a publisher, his young daughter, a naturalist, and a photojournalist—has authored the best of them.

How Big Is It? A Big Book All About Bigness, by Ben Hillman (Scholastic Reference; \$14.99)

Many objects of scientific interest are so very big (or so very small) that

it's difficult to grasp just how big (or small) they are. The giant squid, *Architeuthis dux*, can grow to fifty-five feet. But how long is fifty-five feet? To show his daughter Maizy, five years old at the time, Ben Hillman used photo-editing software to park a giant squid in their home's driveway. That image inspired *How Big Is It?*, a book of startling composites. The two-mile-thick ice sheet that covered the northern hemisphere during the last ice age looms over the Chicago skyline, dwarfing the Sears Tower. The massive corpse flower, *Rafflesia arnoldii*, makes a surreal umbrella for two. Hillman's

witty images will stick in a child's mind long after standard comparisons to the weight of an elephant or the height of the Empire State building are forgotten.

FOR INTERMEDIATE READERS

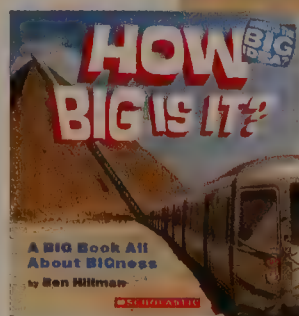
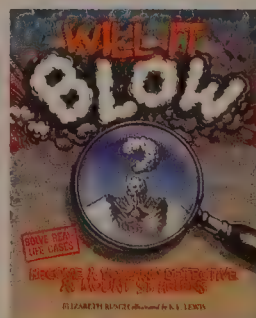
How Underwear Got Under There: A Brief History, by Kathy Shaskan; illustrated by Regan Dunnick (Dutton Children's Books; \$16.99)

Organized around eight functions that underwear has served through the centuries (cleanliness, exaggeration, modesty, protection, shaping, status, support, and warmth), Kathy Shaskan's book takes readers on a fascinating tour of historical solutions to very human problems. Shaskan points out that the smock was the first answer to body odor, that corsets couldn't be laced really tight until metal eyelets were invented, that elastic didn't exist until 1820, and that the bra hasn't even celebrated its centennial yet. Regan Dunnick's lighthearted cartoons perfectly match Shaskan's playful tone.

Will It Blow? Become a Volcano Detective at Mount St. Helens, by Elizabeth Rusch; illustrated by K.E. Lewis (Sasquatch Books; \$18.95)

In 2004, scientists began to detect swarms of small earthquakes under Mount St. Helens, and wondered whether the volcano was about to erupt again. In *Will It Blow?* five volcanologists struggle to understand the data they collect. The reader can speculate with them

as they compare seismograms of the current tremors to those made by a helicopter on the ground and a steam explosion, among other phenomena. The scientists become increasingly baffled by their data. Why is no gas escaping from the rumbling volcano? What's that bulge in the crater floor, and that spot in the glacier that melts and then boils away? Readers won't



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TIGHT LINES

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*For more information: www.yaleanglersjournal.com
52 color illus.



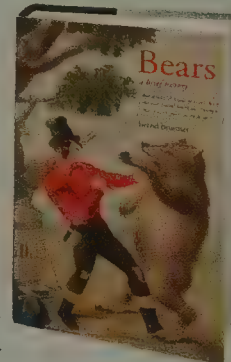
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THE LAST HUMAN

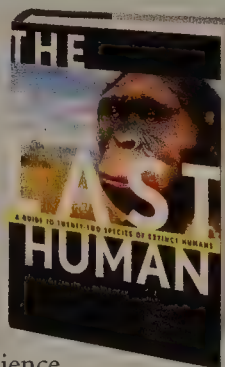
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be able to predict the answer, but the book makes sense of all the clues.

Will It Blow? provides an exciting glimpse into the science of volcanology, but the text is somewhat encumbered by the design. The book is dressed up as a private eye's case file, with notes paper-clipped to documents rubber-stamped "CASE FILE OPEN" OR "CASE CLOSED." Yes, scientists sometimes think like detectives, but the metaphor gets in the way of a story intriguing enough on its own.

Comets, Stars, the Moon, and Mars:

***Space Poems and Paintings*, by Douglas Florian (Harcourt Children's Books; \$16.00)**

In his latest children's book, Douglas Florian, an accomplished poet-painter and father of five, romps through the universe. Each spread features light verse printed over gouache images of planets and other heavenly bodies decorated with collage and rubber stamps. As always, Florian loads his paintings with witty details. Mercury, for example, is outlined in numerous small feet, a glancing reference to Mercury the messenger in Roman mythology.

The book's design entertains as much as its illustrations do. As one turns the pages, celestial bodies dance from left to right and a rusty brown planet glimpsed through a cut-out hole turns bright blue. Playful though the book may be, it is al-

ways accurate. Venus's atmosphere is toxic and Uranus really does spin on its side. Florian accepts the discipline of fact as well as that of poetic form, and so it is always a pleasure to see his name on a book's spine.

FOR ADVANCED READERS

***George's Secret Key to the Universe*,**

by Lucy and Stephen Hawking, with Christophe Galfard; illustrated by Garry Parsons (Simon & Schuster Books for Young Readers; \$17.99)

The first in a three-part series, *George's Secret Key* is an illustrated chapter book written by the renowned physicist Stephen Hawking and his daughter Lucy, a journalist and author. The hero, a boy named George whose parents are technophobe environmentalists, lives next door to Eric, a physicist with a computer that can open portals in spacetime. George, accompanied by Eric's daughter, jumps through the portal to tour the solar system, hitching a ride on a comet.

The joyride is interrupted by a science teacher portentously named G. Reeper. To get his hands on the computer for devious ends, Reeper lures Eric out to the nether regions of the universe, where a black hole swallows the physicist whole. In order to save his neighbor, George must overcome a series of obstacles, including, amusingly, his fear of scientific jargon.

People who know real scientists will appreciate Eric's enthusiasm, naïve idealism, and tendency to lecture. The book gets points for tackling the recurrent tension between environmentalism and science, but it succeeds first and foremost as a good old-fashioned adventure tale.

***Tsunami Warning*, by Taylor Morrison (Houghton Mifflin Company; \$17.00)**

A shocking revelation of the 2004 tsunami was that nations bordering the Indian Ocean had no system for tsunami detection and warning. Nor, for that matter, did the Atlantic coast of the United States. The Pacific coast, however, did have a sensor network, installed after a devastating tsunami hit Hilo, Hawaii, in 1946. Taylor Morrison describes that system, as well as the

advanced warning system that has since subsumed it.

Tsunami Warning, like Morrison's earlier books, *The Coast Mappers* and *Wildfire*, has a slightly old-fashioned feel: his paintings resemble popular graphic arts of the 1940s and his palette of forest green, black, and gray distinguishes

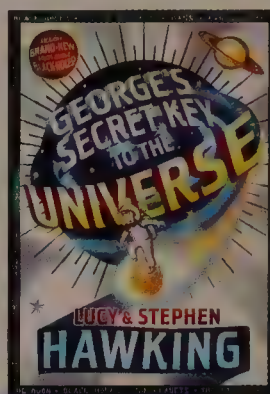
itself from the screamingly bright colors of most modern children's books. Both text and illustrations are of a piece with his subject matter: feats of engineering that have stemmed Nature's blind fury. At a time when environmentalism dominates children's literature and technology is largely ignored, one is grateful that Morrison speaks for the engineers.

The Secret of Priest's Grotto: A

***Holocaust Survival Story*, by Peter Lane Taylor with Christos Nicola (Karben Publishing; \$18.95)**

In 1993 an American caver named Christos Nicola, exploring a maze-like Ukrainian cave south of Kiev, was startled to find hand-built rock walls, old shoes, buttons, and other signs of human habitation. Four years later, he tracked down the cave's inhabitants: three families of Jews, now living in the United States and Canada, who hid in the cave during the Nazi occupation.

The Secret of Priest's Grotto, a photo-illustrated book, interleaves an account



of an expedition to the cave with the story of the families who hid there. Living underground in the seventy-seven-mile-long cave for nearly a year (after five months in a smaller cave), the Jews suffered hypothermia, malnutrition, and sensory deprivation. But the greatest danger was other people. When Ukrainian peasants realized Jews were hiding in Priest's Grotto, they worked for days with picks and shovels to block the entrance. Only two former neighbors remained trusted friends. Had Nicola not been curious about an old shoe and a few buttons, we might never have heard the survivors' story.

Tracking Trash: Flotsam, Jetsam, and the Science of Ocean Motion, by Loree Griffin Burns (Houghton Mifflin Company; \$18.00)

In 1990, during a storm in the Pacific, the ship *Hansa Carrier* lost five containers that held roughly 80,000 Nikes. When more and more sneakers began washing up on beaches, Curt Ebbesmeyer, an oceanographer, decided to track them to their source. He soon realized the sneaker spill was "the largest (and cheapest) ocean drift experiment ever undertaken." Thousands of containers fall overboard every year, so other experiments followed—with bathtub toys, hockey gloves, computer monitors, and more.

After that lighthearted beginning, *Tracking Trash* takes a darker turn. In 1997, Charles Moore, a research-vessel captain, discovered a convergence zone in the North Pacific where plastic bags, shampoo caps, and soap bottles have collected to form a floating garbage patch the size of Alaska. Meanwhile




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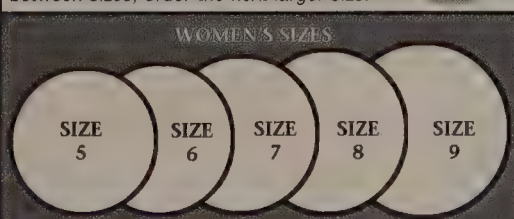
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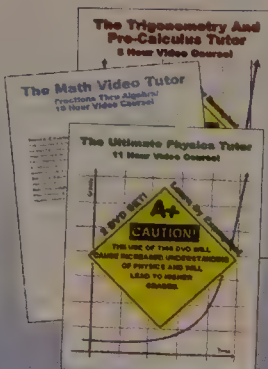
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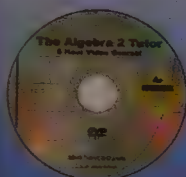
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abandoned, drifting “ghost nets” entangle and kill untold thousands of sea animals annually; scientists are trying to tag and track them with satellites. *Tracking Trash* is the latest in Houghton Mifflin Company’s *Scientists in the Field* series, notable for its high production values and reliance on first-hand reporting. Loree Griffin Burns has loaded the book with information, insight, and intellectual twists.

Alter Ego: Avatars and Their Creators, by Robbie Cooper, Julian Dibbell, and Tracy Spaight (Chris Boot Ltd; \$35.00)

Several years ago, Robbie Cooper, a photojournalist, began asking online gamers to let him photograph them and take a screen grab of their avatar, or game character. *Alter Ego* combines his gamer/avatar image pairs with Tracy Spaight’s interviews. The result is a fascinating glimpse into the psychology of masquerading and secret identities. Clearly, the Internet allows people to shrug off stereotypes that plague them in real life. Beautiful young women enjoy playing undead rogues or warriors because they can do what they want without guys bothering them. A severely disabled man is free online to ride futuristic speed bikes and fight monsters. But other choices scratch more obscure psychological itches, such as a male economics professor whose avatar is a dwarf girl.

Kids will be fascinated by this book, which addresses their culture in an intelligent way. Parents should be warned, however, that *Alter Ego* covers the dark side of gaming, including Chinese “game farms” where chain-smoking young men work twelve-hour shifts to advance wealthy gamers’ avatars. Even nongamers might want to pick up *Alter Ego*, if only because gaming is the future: more than 150 colleges have virtual campuses in the online game *Second Life*.

DIANA LUTZ is a freelance science writer and editor, as well as the former editor of *Muse*, a science magazine for young people. She lives in Madison, Wisconsin.

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AS HEARD ON PAUL HARVEY NEWS Famous EdenPURE® portable heater that can cut your heating bill up to 50% is now much better

Heats a large room in minutes with even heat wall to wall and floor to ceiling

Does not get hot, cannot start a fire and will not reduce humidity or oxygen

By John Whitehead,
Media Services

The famous infrared portable heater, the EdenPURE®, which can cut your heating bills by up to 50%, has been greatly improved.

The new heater heats better, faster, saves more on heating bills and runs almost silent.

You have probably heard about the remarkable EdenPURE® as heard on Paul Harvey News and on television features across the nation.

The EdenPURE® can pay for itself in a matter of weeks and then start putting a great deal of extra money in your pocket after that.

And that's just the start of the benefits for the new EdenPURE® Quartz Infrared Portable Heater.

A major cause of residential fires in the United States is portable heaters. But the EdenPURE® cannot cause a fire. That is because the quartz infrared heating element never gets to a temperature that can ignite anything.

The outside of the EdenPURE® only gets warm to the touch so that it will not burn children or pets. Pets can sleep on it when it is operating without harm.

The advanced space-age EdenPURE® Quartz Infrared Portable Heater also heats the room evenly, wall-to-wall and floor-to-ceiling. And, as you know, portable heaters only heat an area a few feet around the heater. With the EdenPURE®, the temperature will not vary in any part of the room.

Unlike other heating sources, the EdenPURE® cannot put poisonous carbon monoxide into a room or any type of fumes or any type of harmful radiation.

Q. What is the origin of this amazing heating element in the EdenPURE®?

Never be cold again



**Cannot start a fire; a child or animal
can touch or sit on it without harm**

A. This advanced heating element was discovered accidentally by a man named John Jones.

Q. What advantages does infrared quartz tube heating source have over other heating source products?

A. John Jones designed his heating source around the three most important consumer benefits: economy, comfort, and safety.

In the EdenPURE® system, electricity is used to generate infrared light which, in turn, creates a very safe heat.

After a great deal of research and development, very efficient infrared heat chambers were developed that utilize three unique patented solid copper heat exchangers in one EdenPURE® heater.

Q. How can a person cut their heating bill by up to 50% with the EdenPURE®?

A. The EdenPURE® will heat a room in minutes. Therefore, you can turn the

heat down in your house to as low as 50 degrees, but the room you are occupying, which has the EdenPURE®, will be warm and comfortable. The EdenPURE® is portable. When you move to another room, it will quickly heat that room also. This can drastically cut heating bills, in some instances, by up to 50%.

The EdenPURE® heater is now greatly improved. The EdenPURE® comes in 2 models. Model 500-XL heats a room up to 300 square feet and Model 1000-XL heats a room up to 1,000 square feet.

End of interview.

Readers who wish can obtain the EdenPURE® Quartz Infrared Portable Heater at a \$75 discount if they order in the next 10 days. Please see the Special Reader's Discount Coupon on this page. For those readers ordering after 10 days from the date of this publication, we reserve the right to either accept or reject order requests at the discounted price.



New Model Improvements

- 1) The XL runs very much quieter. This type of super efficient fan system produces what is termed white noise which blends into a home atmosphere and becomes virtually inaudible. You now have to put your ear next to the heater to hear it operate. In addition to quieter the new fan blades are able to generate higher pressure air flow which pushes the warmer air out further into the room.
- 2) The XL heats better. The XL thermostat has been vastly improved so that it operates within a tighter range of degrees. The previous model used a mechanical thermostat which could produce a 6 degree variance in heat. This could be uncomfortable especially for the more heat sensitive elderly. The XL's electronic

- thermostat does not only eliminate the problems of a mechanical thermostat, but it is set to a much tighter tolerance. This will promote an extremely more comfortable even stable heat.
- 3) The 1000-XL features digital controls. It has a simple 3 large button control which turns the unit on, and you set the comfort level that you want which reads out on the front of the unit. It also has a remote control so you can adjust the comfort level without getting up.
- 4) The 500-XL has a single on/off switch and adjustable digital thermostat.
- 5) The XL is much more reliable. The thermostat and electronics are all solid state and the infrared bulbs are greatly improved to last for a very long time.

SPECIAL READER'S DISCOUNT COUPON

The price of the EdenPURE® Model 500-XL is \$372 plus \$17 shipping for a total of \$389 delivered. The Model 1000-XL is \$472 plus \$27 shipping and handling for a total of \$499 delivered. People reading this publication get a \$75 discount with this coupon and pay only \$297 delivered for the Model 500-XL and \$397 delivered for the Model 1000-XL if you order within 10 days. The EdenPURE® comes in the decorator color of black with burled wood accent which goes with any decor. There is a strict limit of 3 units at the discount price - no exceptions please.

Check below which model and number you want:

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☐ Model 1000-XL, number _____

- To order by phone, call TOLL FREE 1-800-588-5608 Ext. EPH4963. Place your order by using your credit card. Operators are on duty Monday - Friday 6am - 3am, Saturday 7am - 12 Midnight and Sunday 7am - 11pm, EST.

- To order by mail, by check or credit card, fill out and mail in this coupon.

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And for the Coffee Table

By Laurence A. Marschall

The Deep: The Extraordinary Creatures of the Abyss by Claire Nouvian (*The University of Chicago Press*; \$45.00)

Oceanic Wilderness by Roger Steene (*Firefly Books*; \$59.95)

Until twenty-five years ago, the deep sea was virgin territory to biologists, and even today virtually every research dive into the abyss turns up a profusion of previously unknown

foot of a duck. Since only a few percent of the ocean's depths have so far been explored, one can hardly imagine what phantasms of this remarkable bestiary the next edition will display.

Underwater photographer Roger Steene frequents shallower waters in and around coral reefs throughout the world. In *Oceanic Wilderness* he records underwater scenes few of us have the resources, skill, or patience to behold, rendered with a startling sharpness and brilliance. In one picture a rainbow mantis displays so many colors it looks as if it is wearing a clown costume; even its huge goggle eyes are purple. Elsewhere, collages of close-ups highlight the kaleidoscopic patterns of markings on sponges, sea urchins, and corals. Most remarkable is a series of pictures showing the tender embraces of tropical fish making love (how did he get those shots?). All in all, this collection of undersea glamour is a pleasant foil to the nightmarish vision of *The Deep*.

The Pompeii Pop-Up Text by Peter Riley with Dr. Thorsten Oppen; design by David Hawcock (*Universe Publishing*; \$29.95)

The Red Volcanoes: Face to Face with the Mountains of Fire by G. Brad Lewis and Paul-Edouard Bernard de Lajartre (*Thames and Hudson*; \$34.95)

The catastrophic explosion of Mt. Vesuvius on August 24, 79 B.C. not only put an untimely end to the city of Pompeii, but also etched an impression of the enormous destructive power of volcanoes in our collective memory.

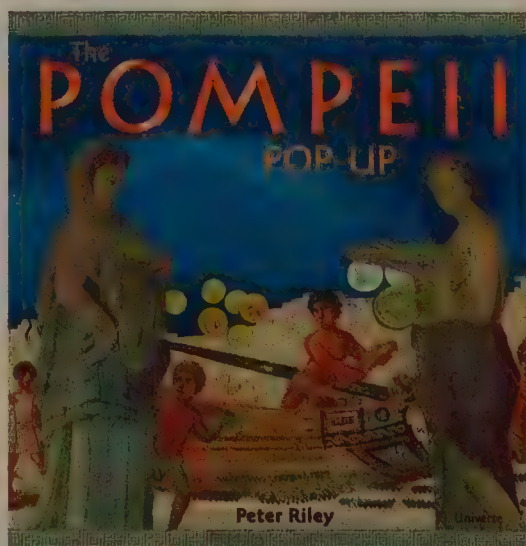
True to form, Vesuvius erupts from the centerfold of this infernally clever Pompeii primer when the book is opened and its scenes unfold. In the foreground, residents desperately try to outrun the blast, or, with equal futility, cower in houses that will soon be sealed under a blanket of ash. Yet the hot ash that interred them froze time in the city, saving it for archaeologists to uncover two millennia later. Now, thanks to paper engineer Hawcock and writers Riley and Oppen (a British Museum curator of antiquities), readers can manipulate 3-D models of Pompeii's old marketplaces, inns, and villas, and explore its monumental forum from the comfort of an armchair. Clearly, Vesuvius was an agent both of destruction and of preservation.

Volcanoes are also agents of creation, especially at places in the Earth's crust where magma wells up to form new land in the sea. Two of the most active of these are Kilauea, on the Pacific island of Hawaii, and Piton de La Fournaise, on the Indian Ocean island of Réunion. Distinct from stratovolcanoes like Mt. St. Helens and Vesuvius, which explode with catastrophic violence, these so-called "red volcanoes" merely ooze and spray, creating meandering lava flows and fantastic pyrotechnic displays that can be viewed, albeit cautiously, with minimal risk.

Two skilled nature photographers, G. Brad Lewis, in Hawaii, and Paul-Edouard Bernard de Lajartre, in Réunion, have devoted years to recording the red volcanoes, creating abstract compositions in earth, darkness, and fire. Daytime views show the delicate



species. In *The Deep*, journalist Claire Nouvian has assembled a portrait gallery of these exotic creatures, accompanied by eloquent essays by more than a dozen ocean scientists. The denizens of the deep are so bizarre they seem to have been sculpted by Salvador Dalí on acid. Fish with skeletal heads and protruding fangs glow into the camera, some with lower teeth so long that a reckless bite could take out their own eyeballs. Smooth-skinned octopuses float in the blackness, resembling embryos attached to bundles of wormlike tentacles. Other creatures look like ball-point pens, paper lanterns, baby's buttocks, and Pokémon cartoon figures, while the spooky vampire squid reminded me of a bat's head grafted onto the webbed



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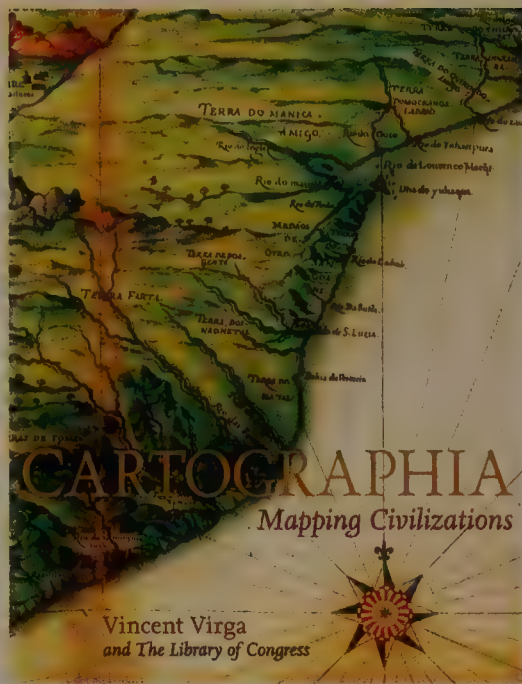
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texture of cinder, lava, and venting gases, but the nighttime shots, in their simple beauty, are the most compelling. In one, a splash of orange-red lava bursts into the blackness, its tracery suggesting the quiet power of the famous wave woodcut by Japanese artist Hokusai. In another, thin rivulets of lava, looking like the glowing fangs of a dragon, drip from an elongated precipice into the ocean.

Cartographia: Mapping Civilizations
by Vincent Virga and the Library of Congress (Little, Brown and Company; \$60.00)

If a picture is worth a thousand words, then a map is worth at least a thousand pictures. Not only does each place on a map evoke a story, but so too does the map itself: we want to know who made it and why, and what impact the map had on those who used it. Picture editor Vincent Virga,



drawing on the resources of the Library of Congress, which houses the largest cartographic collection in the world, lays forth a spectacular cultural history of cartography, organized by geographic region—starting with the Mediterranean, the oldest region to be mapped, and ending in Antarctica.

The highlights of the book, of course, are exquisite reproductions of noteworthy examples of the cartographic art, from a Babylonian world map—an abstract diagram of circles, lines, and symbols inscribed on a clay tablet—to a 1996 chart of the estuary of the Mississippi, so detailed it seems almost to replicate the river itself. Though cartography has obviously become more precise with time and technology, it is clear from this book that the history of mapmaking is not just a constant striving for geographic verisimilitude. Mapmakers usually had other things in mind. A seventh-century Persian chart represents land in the shape of a bird, a poetic vision of the motherland. As recently as the nineteenth century, a Japanese map of the prefecture around Mt. Fuji embodies more artistic stylization than true-to-life rendition. And even when the goal of the mapmakers

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was strictly utilitarian, their maps often displayed truths that were political, social, economic, or military rather than strictly topographic. That is what makes maps so delightful and fascinating: they do not show us the world as it is, but rather the world as seen through other eyes, in other places and times.

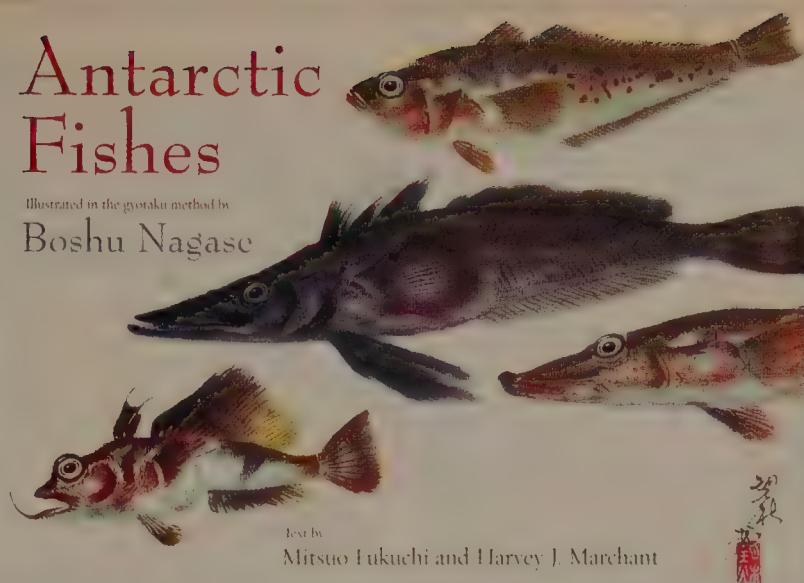
Vanishing World: The Endangered Arctic Photographs by Mireille de la Lez; text by Fredrik Granath (Abrams; \$40.00)

Antarctic Fishes Illustrations by Boshu Nagase; text by Mitsuo Fukuchi and Harvey J. Marchant (The Johns Hopkins University Press; \$45.00)

Mireille de la Lez and Fredrik Granath spent five years at the top of the world, traveling by sledge and

Antarctic Fishes

Illustrated in the gyotaku method by
Boshu Nagase



Text by
Mitsuo Fukuchi and Harvey J. Marchant

snowmobile, tenting in snowdrifts, and keeping a wary eye out for angry polar bears, hidden crevasses, and swiftly advancing blizzards. The photographs that they worked so hard to create are beautifully reproduced here in full color, but they depict a world etched mostly in subtle tones of blue-gray and white. There are intimate close-ups of bears—in repose, jumping

through the snow, swimming in watery leads between drifting floes of ice. There are equally detailed portraits of walruses, arctic foxes, whales, and arctic terns. And there are gorgeous landscapes, organic forms sculpted in ice and rock or ice and water. Except for a few paragraphs here and there, none of the pages are captioned, as if the authors relied on the

Arctic to speak for itself. And speak it does: these images of barren, rugged terrain and hardy, solitary animals convey an overwhelming sense of the lonely and precarious state of life in the far, far North.

From the opposite pole of the Earth comes *Antarctic Fishes*, an illustrated catalog by a polar marine ecologist and an Antarctic biologist

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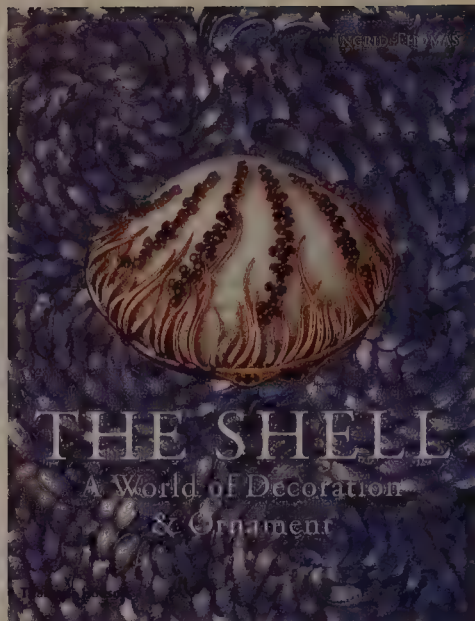


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of the finned species that swim the southernmost oceans. Readers will want it on their coffee tables, but not as a field guide; few of us will ever encounter a Nichol's lanternfish or a sailfin plunderfish, either in the wild or at the fish market. The book's appeal, rather, is in its illustrations, produced by the unusual Japanese art of *gyotaku*, or "fish rubbing." In *gyotaku* (which was developed in the mid-1800s, and so is no more ancient than photography), a thoroughly washed fresh fish—in this case, fresh-frozen for transport from the Antarctic—is covered in clinging, semi-transparent tissue paper. Then layers of colored inks are carefully dabbed

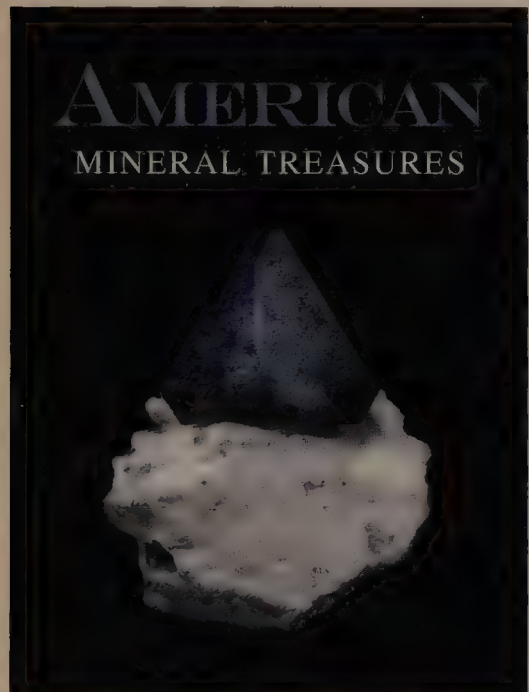


undulating ribbons, ovoids, and cones, as well as phantasmagorical forms with spikes and excrescences that seem to deliberately defy any notion of regularity. Some shell surfaces seem to bear the monochrome glaze of primitive pottery; others are as crowded with iridescent jewels as a Fabergé egg.

Ingrid Thomas, an artist and conchologist,

draws from her extensive collection and research in *The Shell: A World of Decoration and Ornament*, but while the illustrations here are as meticulously reproduced as Starosta's photographs, Thomas's book is far more than a gallery of natural forms. Thomas provides an ample text and more than 500 photographs and art reproductions to show how shells and shell-like forms have been used in jewelry, pottery, domestic design, and a wide variety of other decorative and fine arts from prehistoric times to the present. What difficulty Thomas must have had choosing only 500 examples of this lovely craftsmanship! Should she have left out the ornate cup made from a nautilus shell in early seventeenth-century Holland, cut to the shape of an ostrich's body, with neck, head, and legs made of pure gold? Or the pectoral ornament from New Guinea, embroidered with hundreds of cowrie and nassa shells? Or the Art Nouveau alabaster table light sculpted in the shape of a conch shell, with a young maiden emerging, Venus-like, from its interior? Looking at what Thomas did include, one can only wish for a book with twice as many pages, and perhaps for coffee tables twice as strong.

LAURENCE A. MARSCHALL, author of *The Supernova Story*, is W.K.T. Sahn Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.



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over the surface using a cotton wad. When the tissue is lifted off and laid flat, a luminously textured, anatomically accurate rendition of the living creature appears. Each of the fifty-four plates in *Antarctic Fishes* was created by this process, and each print, bearing the calligraphic signature of *gyotaku* master Boshu Nagase, stands on its own as an elegant and informative work of art.

Shells by Paul Starosta and Jacques Senders (Firefly Books; \$85.00)

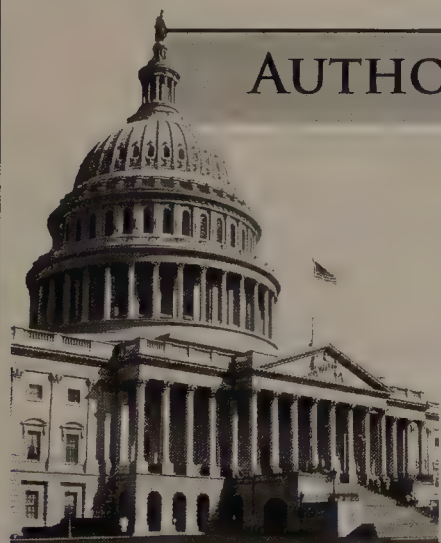
The Shell: A World of Decoration and Ornament by Ingrid Thomas (Thames & Hudson; \$65.00)

These opulent books document two of the world's most dazzling collections of shells. *Shells*, photographed by Paul Starosta, showcases the one malacologists Jacques and Rita Senders assembled over fifty years of travel and diving. There's a brief introductory essay by architect Paolo Portoghesi, noting how the shell has influenced art and building, from King Solomon's Temple to the Sydney Opera House. But the real treasure of this book is more than 300 pages of heart-stopping photographs. Starosta has posed every specimen against a black background, lit dramatically from the front and above, and sometimes from behind as well, to emphasise symmetries in shape and nuances in color. Leafing through the pages, the senses are overloaded with variations on a few repeating themes: hearts, spirals, fans,

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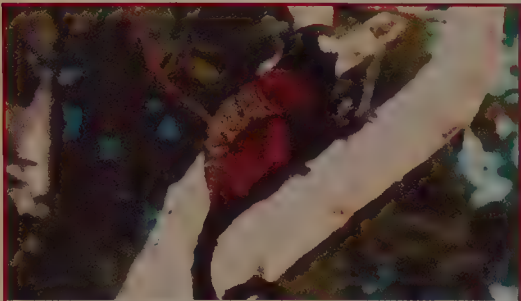
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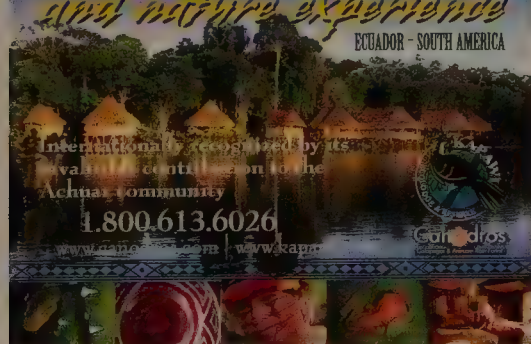
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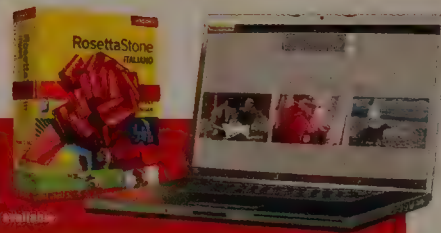
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WORD EXCHANGE

Continued from page 8
taken a few seconds of beeping from WWV for Sputnik's beeps.

Carl F. Welser
Hamburg, Michigan

Cutting-edge Science?

I cringed at the description of the surgery on the pregnant ewe ["A Human Cell in Sheep's Clothing," 7-8/07]. Author and surgeon seem oblivious to the operation's severity and the ewe's painful recovery.

Laurie Sexton
New York, New York

OLIVIA JUDSON REPLIES: I am not used to seeing surgery, so I expected to be horrified; instead, I was impressed. The surgeon was not at all callous, and the sheep was given the same care that a human patient would get, including pain killers. After such an operation, sheep usually appear to be back to normal within an hour or so.

Erratum

In last month's biographical note for Sandra L. Postel ["Contributors," 11/07], the Global Water Policy Project she founded was mistakenly identified as "geared toward sustaining the Connecticut River watershed." Though based in western Massachusetts, the project is designed to promote the preservation and sustainable use of freshwater throughout the world, through research, writing, outreach, and public speaking. The error was introduced during editing of the biographical text provided by the author, and slipped through our fact-checking process. For information on the Global Water Policy Project see www.globalwaterpolicy.org

NATURAL HISTORY welcomes correspondence from readers. Letters should be sent via e-mail to nhmag@naturalhistorymag.com or by fax to 646-356-6511. All letters should include a daytime telephone number, and all letters may be edited for length and clarity.

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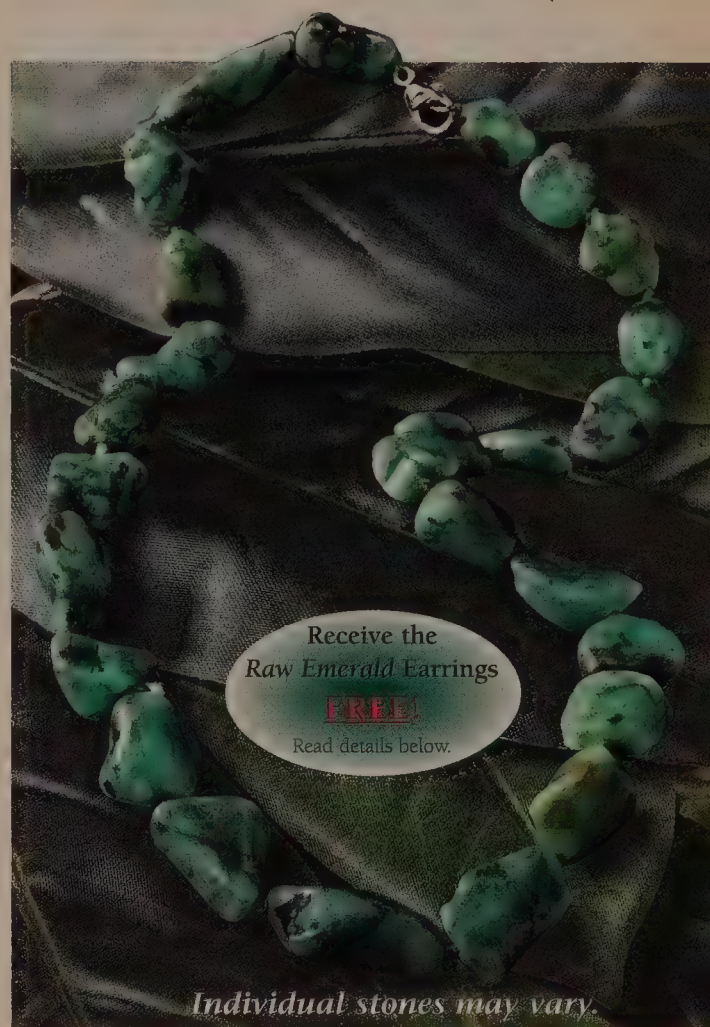
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Mercury is difficult, if not impossible, to view in December; it is at superior conjunction with the Sun (on the opposite side of the Sun from Earth) on the 17th. In January, however, Mercury will be an evening object, setting after the Sun, and by the 9th should be visible with the naked eye. The planet swings widest of the Sun on the 22nd, its tiny disk a little more than half illuminated from our point of view. Decreasing rapidly in brightness and phase after that peak performance, Mercury fades precipitously.

Venus rises in the east to east-southeast between 3:15 and 4:15 A.M. local time during December. At the beginning of the month that is about two hours before the first hint of dawn. By the time morning twilight is under way, Venus shines fairly high in the southeast as the December "Morning Star." It gradually sinks a little lower during the month, and by the end of January it rises less than a half hour before the start of morning twilight. During the latter half of January Venus slowly approaches Jupiter, much lower in the sky; they'll be closest together on February 1, when they'll be separated by only 0.6 degrees.

Mars rises at about 6:20 P.M. local time at the beginning of December, some fifteen minutes after evening twilight ends, but just a week later it is already above the horizon as twilight fades to night. The planet is retrograding (moving westward) through the stars of Gemini, the Twins, and will cross over into Taurus, the Bull, on December 30. Along the way it will arrive at opposition to the Sun (on the opposite side of Earth from the Sun) on Christmas Eve, when it will be visible all night long, shining at magnitude -1.6 and passing nearly overhead at midnight as seen from the southernmost United States.

The Red Planet will be 54.8 million miles from Earth on December 18, its minimum distance for 2007. That's 11.7 million miles farther away than at our

last close encounter, which occurred just before Mars reached opposition to the Sun in 2005. On this upcoming occasion, however, Mars will climb much higher in the sky. This apparition of Mars is the best we'll get until 2016; a good 4-inch telescope should show Mars's bright north polar cap and quite a few dark features (the maria, or "seas")—on those nights when the atmosphere is steady.

In January, Mars increases its distance from Earth to 72.3 million miles, and in the process fades almost a full magnitude, from -1.5 to -0.6 . A little higher above the eastern horizon each day at dusk, the Red Planet (shining yellow-orange) continues to move "backwards" into Taurus. It will sit between the Bull's horns on January 30, when it resumes its normal forward (eastward) motion against the star background.

Jupiter might be glimpsed with binoculars in the evening sky during the first few days of December, just above the southwestern horizon about fifteen or twenty minutes after sunset. It then falls completely out of sight, passing behind the disk of the Sun on December 23. The planet starts the New Year as undetectable, rising less than thirty minutes before the Sun, but each morning it appears about three minutes earlier and gets a little higher before it disappears in the morning light. By month's end it will team with Venus (about seven times brighter) to make an eye-catching duo low in the southeast, visible as morning twilight begins to brighten.

Saturn is in Leo, the Lion, during December and January; it can be found about 8 degrees to the east of Leo's brightest star, Regulus. The planet rises soon after 11 P.M. local time in early December. By New Year's Eve it's coming up before 9:30 P.M., and by the end of January, it will rise soon after 7 P.M. and will reach its highest point in the sky around 2:00 the following morning. The planet's famous ring system, observable through small

telescopes, is now tilted less than 7 degrees to our line of sight.

Many observers consider the **Geminid meteor shower**, expected between December 7 and 17, to be the best shower of the year. The peak will be the night of December 13–14, when up to 120 meteors may be seen every hour under ideal dark-sky conditions. The Geminids are one of the few showers that perform well before midnight. On the evening of the 13th, the waxing crescent Moon sets around 8:15 P.M. local time. By then, the shower's "radiant" (the place in the sky from which the meteors seem to fan out), near the star Castor, is quite high—20 or 30 degrees up in the east—so the meteor rates should be appreciable.

The **Moon** reaches Last Quarter on December 1 at 7:44 A.M. The New Moon falls on December 9 at 12:40 P.M.; First Quarter is on the 17th at 5:18 A.M.; and the Full Moon appears on the 23rd at 8:16 P.M. Last Quarter occurs for a second time in December on the 31st, at 2:51 A.M. In January New Moon occurs on the 8th at 6:37 A.M.; First Quarter is on the 15th at 2:45 P.M.; and Full Moon is on January 22 at 8:34 A.M. Last Quarter comes on January 30 at 12:03 A.M.

The **solstice**, when the Sun arrives at that point where it is farthest south of the celestial equator, takes place on December 22 at 1:10 A.M. Winter officially begins in the Northern Hemisphere, and summer begins in the Southern Hemisphere.

Earth will arrive at **perihelion**—the closest point in its orbit to the Sun—on January 2 at 7:00 P.M. To get to the Sun you would have to travel only 91.4 million miles.

JOE RAO (hometown.aol.com/skywayinc) is a broadcast meteorologist and an associate and lecturer at the Hayden Planetarium in New York City. Unless otherwise noted, all times are eastern standard time.



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D. FINNIN/AMNH

Young and very, very old: Leonye Dreiser, 12, and her brother Luis, 9, of Cologne, Germany, take in the brilliant hues of the 80-million-year-old ammonite fossil recently installed in the Museum's Grand Gallery.

If your idea of fossils is dull, dusty, old bones, a dazzling new specimen on display in the 77th Street Grand Gallery at the American Museum of Natural History is sure to challenge that notion. The fossilized shell of an ammonite that lived approximately 80 million years ago is alive with color, shimmering with orange, yellow, purple, red, and green like psychedelic mother-of-pearl.

The two-foot-diameter fossil is a large and particularly rare example of a marine cephalopod that was once one of the most common invertebrates in the ocean. They went extinct around 65 million years ago, after a massive asteroid impact wiped out nearly half of all living species, including most of the dinosaurs, at the end of the Cretaceous Period.

The name ammonite comes from the Egyptian god Ammon, whose ram-like horns resemble the spirals in the sea creature's shell. The shape of the shell is reminiscent

of today's chambered nautilus, but the ammonite's nearest living relative is the modern squid.

High temperatures and pressures acting on this shell for millions of years preserved its iridescent nacreous layers. Ammonite fossils that exhibit this characteristic are known as ammolites, and share the spotlight with amber and pearl as one of only three gemstones produced by living organisms.

Scientists greatly value ammonites, colorful or not, as clues to the relative age of the rocks in which they are found, because different species of ammonites lived during different time periods. Their presence also indicates the location of ancient seas, such as the Western Interior Seaway in the middle of North America where this ammonite lived.

The fossil was unearthed by ammolite miners near Lethbridge in Alberta, Canada, and donated to the Museum by Korite International and Canada Fossils Ltd.



R. MICKENS/AMNH

Holiday Spirits

This year, the Origami Holiday Tree (on view through January 1) is more magical than ever, teeming with the stuff of legends and fables: dragons, mermaids, unicorns, as well as real animals like narwhals and peacocks, echoing the popular exhibition *Mythic Creatures*, which closes January 6.

The approximately 500 enchanting ornaments were crafted by members of Origami USA to match the tree's theme, *Fantastic Creatures: Mythic and Real*. The tree, a Museum tradition for over 30 years, is located in the Theodore Roosevelt Memorial Hall on the first floor. As in years past, volunteers will be on hand to teach visitors the ancient art of paper folding.

Rethinking *Velociraptor*

New Study Finds They Had Feathers

Remember those rapacious *Velociraptors* stalking children in the film *Jurassic Park*? It appears now that these prehistoric predators could use a costume change: they weren't leathery-skinned toughs after all!

Scientists have known for years that many dinosaurs had feathers. Now, after a new look at some old bones, paleontologists at the American Museum of Natural History and the Field Museum have documented the presence of feathers in *Velociraptor*, one of the most iconic of dinosaurs and a close relative of birds.

The fossil specimen the group examined was a *Velociraptor* forearm unearthed in Mongolia in 1998. They found on it clear indications of quill knobs—places where the quills of secondary feathers, the flight or wing feathers of modern birds, were anchored to the bone with ligaments. Quill knobs are also found in many living bird species and are most evident in birds that are strong flyers. Those that primarily soar or that have lost the ability to fly entirely, however, were shown in the study to typically lack signs of quill knobs.

"A lack of quill knobs does not necessarily mean that a dinosaur did not have feathers," said Alan Turner, lead author on the study and a graduate student of paleontology at the AMNH and at Columbia University in New York. "Finding quill knobs on *Velociraptor*, though, means that it definitely had feathers. This is something we'd long suspected, but no one had been able to prove."

The *Velociraptor* in the current study stood about three feet tall, was about five feet long, and weighed about 30 pounds. These dimensions, coupled with relatively short forelimbs compared to a modern bird, indicate this creature could not fly. The authors sug-

gest that perhaps an ancestor of *Velociraptor* lost the ability to fly, but retained its feathers. In *Velociraptor*, the feathers may have been useful for display, to shield nests, for temperature control, or to help it maneuver while running.

"The more we learn about these animals, the more we find that there is basically no difference between birds and their closely related dinosaur ancestors like *Velociraptor*," said Mark Norell, Curator in the Division of Paleontology at the American Museum of Natural History and coauthor on the study. "Both have wishbones, brooded their nests, possess hollow bones, and were covered in feathers. If animals like *Velociraptor* were alive today our first impression would be that they were just very unusual-looking birds."

The research team also included Peter Makovicky from the Field Museum in Chicago. The work was supported by the National Science Foundation and the American Museum of Natural History, and a paper describing the discovery appeared in the September 21, 2007, issue of the journal *Science*.



MATT MARTINIUK

An artist's rendition of *Velociraptor* in life

Saturdays in Winter: We're All Wet!

In four workshops on Saturday afternoons in January and February, youngsters are invited to delve into the science of water, the subject of *Water: H₂O = Life*, the engaging exhibition that opened in November and runs through May 26, 2008.

In the first hands-on session, on Saturday, January 12, children will ponder the presence of water on Mars, learning how we have come to know that there was water on the Red Planet, and discuss the implications of that knowledge. Next, in a hydrology workshop, children will explore the basic engineering principles that underlie the design of dams and ancient waterways. The third session revolves around the unique properties that make water the only substance able to exist in three phases—gas, liquid, and solid—in the normal range of Earth's temperatures. In the final workshop, children will construct their own terrariums to learn about groundwater, where it comes from, and why it is so important.

Two separate series of workshops are being offered, one for children ages 4 through 6 accompanied by an adult, and the other for children 7 through 9. Participants who attend all four sessions will earn a certificate.



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Water: H₂O = Life is organized by the American Museum of Natural History, New York (www.amnh.org), and Science Museum of Minnesota (www.smm.org) in collaboration with Great Lakes Science Center, Cleveland; The Field Museum, Chicago; Instituto Sangari, São Paulo, Brazil; National Museum of Australia, Canberra; Royal Ontario Museum, Toronto; San Diego Natural History Museum; and Singapore Science Centre with PUB Singapore.

The American Museum of Natural History gratefully acknowledges the **Tamarind Foundation** for its leadership support of *Water: H₂O = Life*, and the Johns Hopkins Center for a Livable Future for its assistance.

Exclusive corporate sponsor for *Water: H₂O = Life* is **JPMorgan**.

Water: H₂O = Life is supported by a generous grant from the **National Science Foundation**.

The support of the National Oceanic and Atmospheric Administration is appreciated.

The Museum extends its gratitude to the Panta Rhea Foundation, Park Foundation, and Wege Foundation for their support of the exhibition's educational programming and materials.

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Mythic Creatures: Dragons, Unicorns, and Mermaids is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with The Field Museum, Chicago; Canadian Museum of Civilization, Gatineau; Australian National Maritime Museum, Sydney; and Fernbank Museum of Natural History, Atlanta.

Mythic Creatures is proudly supported by **MetLife Foundation**.

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Through April 6, 2008
Exquisite images from unmanned space probes take visitors on a journey through the alien and varied terrain of our planetary neighbors.

The presentation of both *Undersea Oasis* and *Beyond* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Unknown Audubons: Mammals of North America

Through August 2008
The stately Audubon Gallery showcases gorgeously detailed depictions of North American mammals by John James Audubon, best known for his bird paintings.

Major funding for this exhibition has been provided by the Lila Wallace-Reader's Digest Endowment Fund.

LECTURES

Wolf Empire

Tuesday, 12/11, 7:00 p.m.
With wildlife photographer and environmentalist Scott Ian Barry.

The 3.5 Billion-Year History of the Human Body

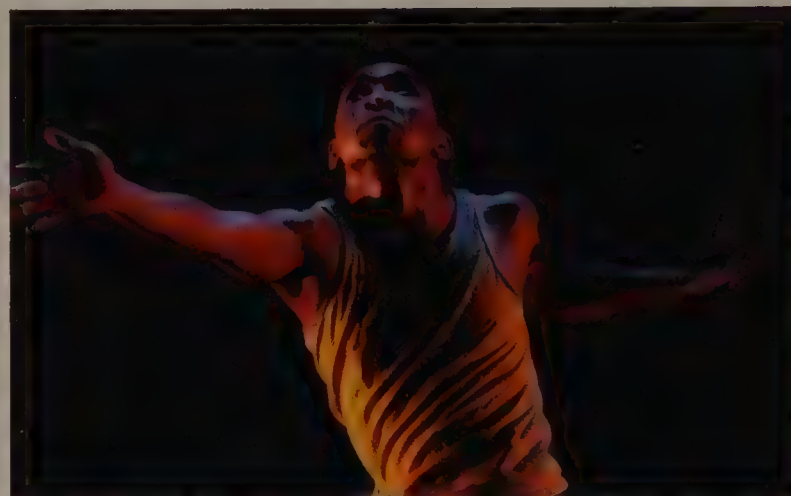
Wednesday, 1/23, 6:30 p.m.

With Neil Shubin, University of Chicago, Department of Organismal Biology and Anatomy.

WORKSHOPS

Lunchtime Winter Bird Walks

Three Wednesdays, 1/30–2/13,
12:00 noon–1:30 p.m.



The Ron K. Brown/Evidence Dance Company will perform at Kwanzaa.

GLOBAL WEEKENDS

The City Celebrates Kwanzaa
Saturday, 12/29, 12:00 noon–
5:00 p.m.

Celebrate Kwanzaa's seven principles, the *Nguzo Saba*, with an afternoon of song, dance, and spoken word.

This event is coproduced by Community Works and the New Heritage Theatre Group under the artistic direction of Sistah Aziza.

Living in America: Rivers of Life

Three Saturdays, 1/12–26,
12:00 noon–5:00 p.m.
Consider the meanings, uses, and values placed on water with performances, discussions, films, and workshops for adults and families.

Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, the New York City Council, and the New York City Department of Cultural Affairs. Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

With Paul Sweet, Collections Manager, AMNH Department of Ornithology.

Understanding Our DNA

Three Thursdays, 1/31–2/14,
6:30 p.m.

Participants sequence their own DNA and discuss their findings.

Public programs are made possible, in part, by the Rita and Frits Markus Fund for Public Understanding of Science.



ROSE CENTER FOR EARTH AND SPACE

Sets at 6:00 and 7:30 p.m.
Friday, 12/7

The 7:30 performance will be broadcast live on WBGO Jazz 88.3 FM.

Friday, 1/4

Visit www.amnh.org for lineup.

FAMILY AND CHILDREN'S PROGRAMS

Field Trip to the Moon

Every Wednesday, 10:30 a.m.
Fly to the Moon in the Hayden Planetarium, guided by a live presenter.

Adventures in Cryptozoology

Saturday, 12/1, 1:00 p.m.
Discover the world of "hidden" creatures, such as Bigfoot, with Loren Coleman, one of the world's leading cryptozoologists.

WATER SATURDAYS

Hands-on workshops; take all four and earn a certificate.
11:00 a.m.–12:30 p.m. (Ages 4–6, each child with one adult)
1:30–3:00 p.m. (Ages 7–9)

Water on Mars?

Saturday, 1/12

Hydrology Workshop

Saturday, 1/19

The Properties of Water

Saturday, 1/26

Groundwater and the Water Cycle

Saturday, 2/2

HAYDEN PLANETARIUM PROGRAMS

LECTURES

Why Are We So Lonely?

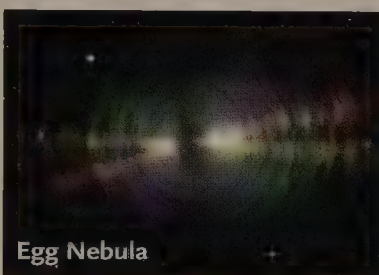
Monday, 12/3, 7:30 p.m.

With Chris Impey, University of Arizona, Department of Astronomy.

Supercollider

Monday, 1/14, 7:30 p.m.

With Chris Tully, Princeton University, and Nima Arkani-Hamed, Harvard University.



Egg Nebula

NASA, W. SPARKS (STSC), AND R. SAHA (JPL)

TUESDAYS IN THE DOME

Virtual Universe

How Deep Is the Universe?

Tuesday, 12/4, 6:30–7:30 p.m.

A New Year in the Milky Way

Tuesday, 1/8, 6:30–7:30 p.m.

Celestial Highlights

Myths in the Winter Sky

Tuesday, 1/29, 6:30–7:30 p.m.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions

Journey into deep space to explore the hypersonic impacts that drive the formation of our universe. Narrated by Robert Redford.

Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum.

Made possible through the generous support of CIT.

Cosmic Collisions was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

IMAX MOVIES

Dinosaurs Alive!

Great dinosaur finds by

AMNH scientists past and present come to life with archival and contemporary footage and scientifically accurate, computer-generated images.



R. MICKENS/AMNH

One Step Beyond brings the party to the Rose Center.

LATE NIGHT DANCE PARTY

One Step Beyond

Friday, 1/25, 9:00 p.m.–1:00 a.m.

This monthly party in the Rose Center features the biggest names in techno, electronica, and indie rock. Food and drink keep the party going.

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., and Saturday, 10:00 a.m.–4:00 p.m., or visit www.amnh.org. A service charge may apply. All programs are subject to change.

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

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Who's Watching Whom?

Story and photographs by Barbie Bischof

To make ends meet during the summer—a season when graduate students like me often lack funding—I took the job of “naturalist” aboard the *Juliet*. The 104-foot, steel-hulled, three-masted schooner embarks out of Miami each week. Carrying about fifteen passengers, mostly scuba divers, she leapfrogs along the reefs of the turquoise and teal-ribboned waters of the Bahamas.

When your life is at sea, time passes differently, and every voyage is unique, even if you’ve been in the same waters hundreds of times. But some of those moments stick to your soul and change your perspective forever. Such an event began one sunset when the *Juliet* was anchored in preparation for a night dive: suddenly a pod of more than one hundred dolphins came toward the schooner from all sides. My shipmates and I watched as they jumped and dove, surrounding our boat; and then, in a matter of minutes, they vanished into the dying embers on the horizon. For the next three days, about ten dolphins—primarily Atlantic spotted dolphins (*Stenella frontalis*)—paid us a visit two or three times each day.

When someone spotted “our” dolphins, the dive master and I would each grab a mask, snorkel, and fins, and with an approving nod from Captain John, we’d leap overboard. Typically, dolphins in the wild ignore humans. Yet in my struggle to keep up with the creatures, I accidentally hit on a way to

get their attention. I would free-dive down about fifty feet—and here’s the key—kicking with my legs and feet locked together, like a dolphin. Seeing this, seven or eight members of the small pod would immediately rush towards me and then swim alongside, clicking and squeaking.

If I turned, they’d turn; if I spun, they’d spin. They nailed my every move. When I ran out of breath, I’d head up. Some of my escorts would bolt ahead with effortless flicks of their tails. Those defectors would wait in a circle near the surface, and watch as I emerged in its center for much-needed air. Taking a few short gasps, I’d quickly dive again. They lingered until I was about ten feet under, before swooshing down around me. After the fifth or sixth round of our up-and-down game, my energy spent and my head light from the want of air, I needed to rest. But a rest broke our rhythm and usually ended the game.

IN MY OWN RESEARCH around the reefs of the Western Atlantic, particularly at the edges of coral “walls,” as divers call them, I’ve encountered barracuda, rays, sharks, turtles, reef fish galore, a few manatees, a right whale, and more, but typically I was ignored or avoided. These dolphins, however, chose to interact: in fact, they were playing with me, rather than vice versa. Their frenetic reaction to my swimming style reminded me of the

way researchers get excited when a chimp copies human behavior. They made eye contact, peering into my mask and inspecting me as we swam side by side. I felt as if I was in their laboratory, possibly a subject in an experiment.

Each diving experience was exhausting but utterly amazing. The creatures never made physical contact, though I was only inches away. Once I tried, but they avoided my touch, and I didn’t want to spoil it.

The *Juliet* saw its little pod for the last time in the early afternoon of the day we sailed back home to Miami. Needing to stay on schedule, we could no longer stop. We watched the dolphins from the bowsprit as they surfed and played in the pressure wake. After about an hour, they simply moved off towards the northwest to deeper water as they had done so many times before.

BARBIE BISCHOF is a doctoral student in the Department of Geography at Florida State University. Her work focuses on the social aspects of marine science and policy.

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